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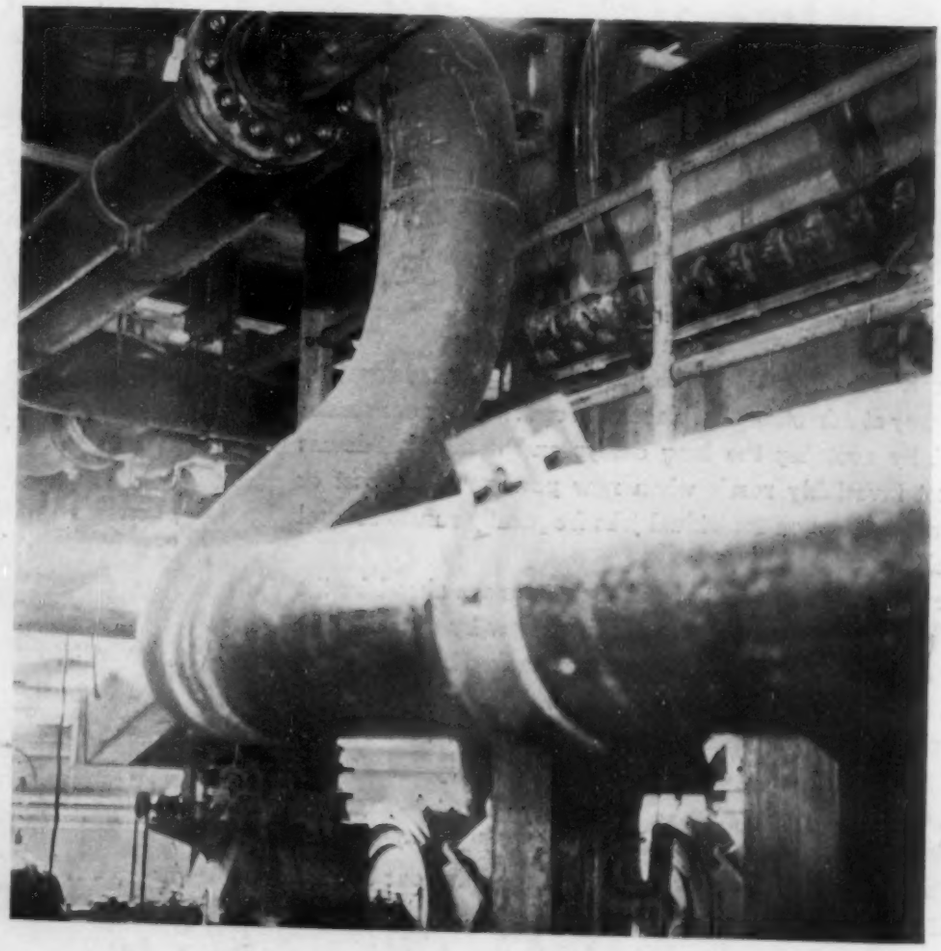

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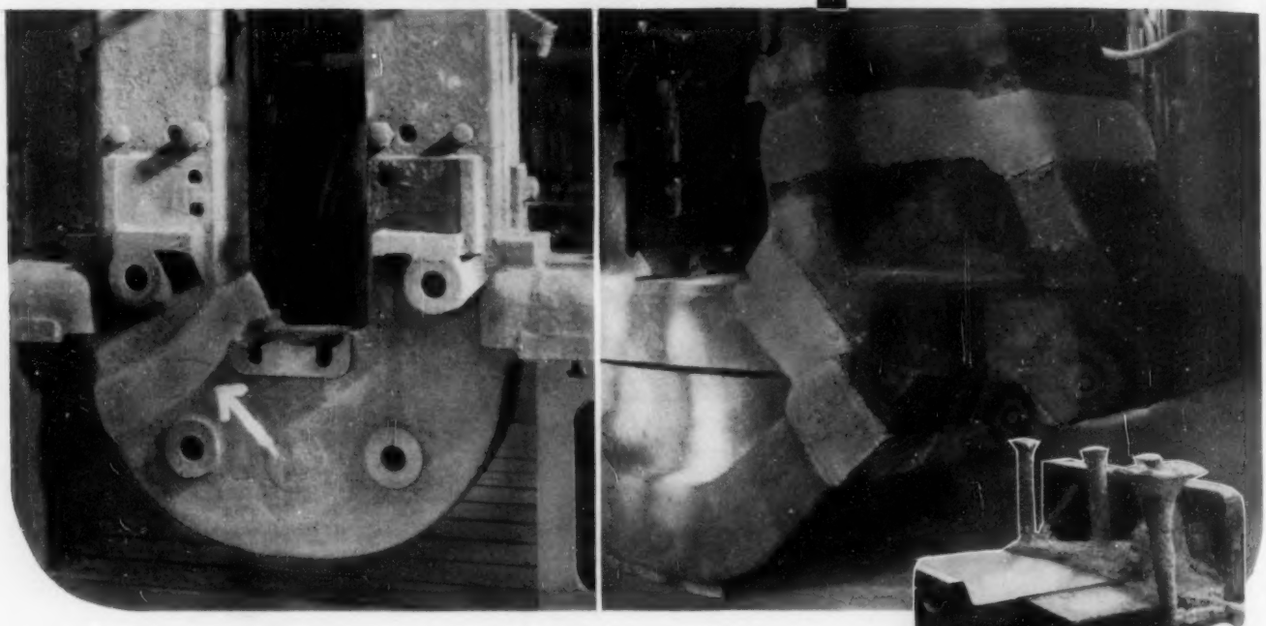

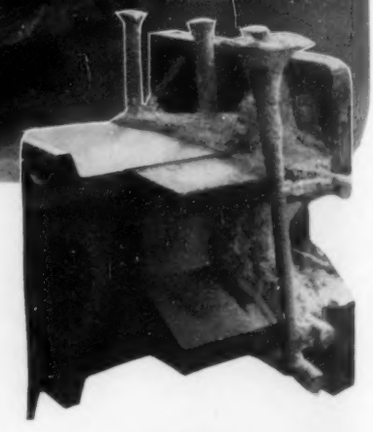

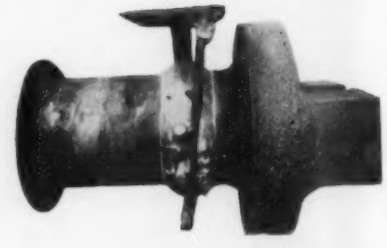

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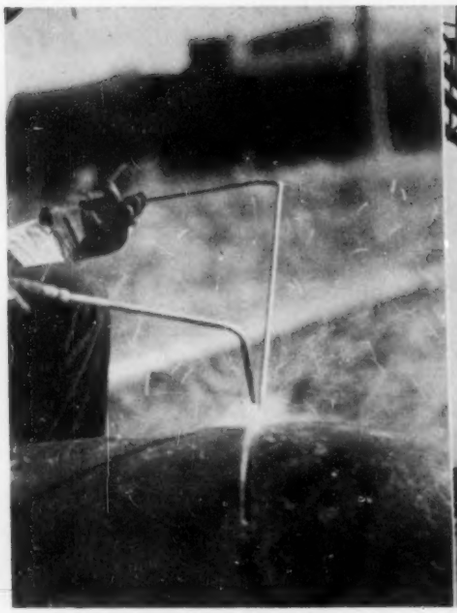


Close-Up of Gas Welding

A Section of the Line in the Steel Structure

Cutting and Beveling Pipe to Correct Length

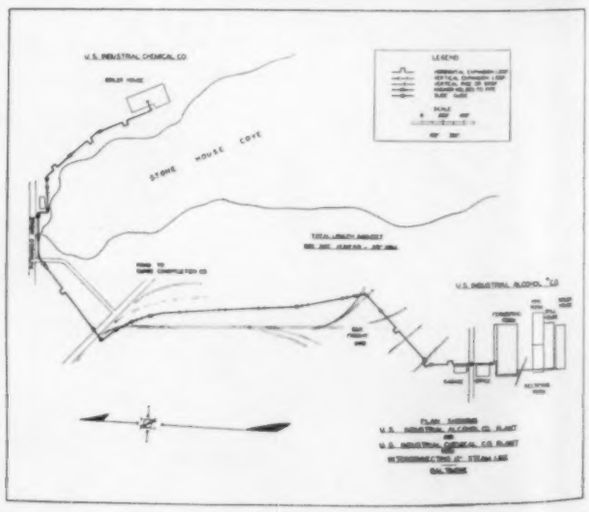
High Pressure Piping*

By J. A. FREIDAY†

CHEMICAL industry plants use large amounts of piping for power, heating process and water lines and it is logical that they should use welding to join these piping systems since welding assures reliable, permanent, strong, leakproof joints.

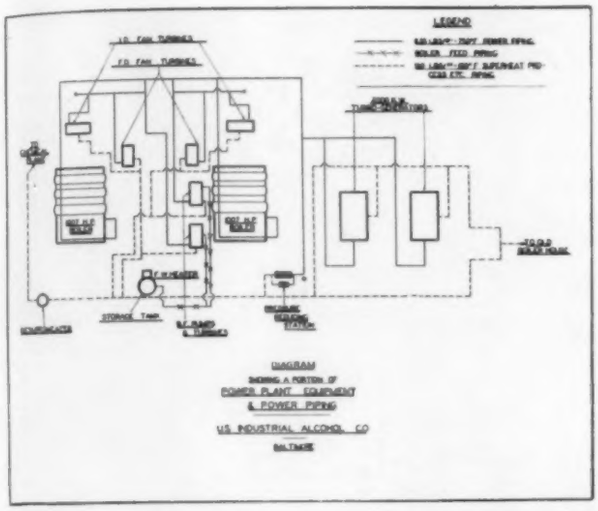
About a year ago the U. S. Industrial Alcohol Co. decided to recondition its Baltimore Plants. This work involved the reconstruction of many old buildings, new construction and a complete new steam generating system to supply steam for power, process and heating. The layout of the Baltimore Plants is unusual in that they are about half a mile apart "as the crow flies." The U. S. Industrial Alcohol Co. plant is located in Curtis Bay while the U. S. Industrial Chemical Co. plant (a subsidiary) is located in Fairfield, a half mile distant across Curtis Bay; the distance by land is over a mile and a half. Each of these units had their own steam-generating plants, operating at 150 lb. per sq. in. which were sorely in need of repair. It was imperative that a new steam-generating system be provided to replace the old and care for future expansion.

After a careful analysis of many methods of steam generation and utilization, it was decided to build a high pressure, high temperature system at the Alcohol Plant in Curtis Bay. The steam is first run through back pressure turbines, thereby generating the electric power for plant use, and then taken from the turbine exhausts for process and other uses in both plants. The final design comprehends the generation of steam at 625 lb. per sq. in. and 750° F., total temperature. This steam is fed to two G. E. back pressure turbines driving 2000-kw. 2300-volt A.C. generators. Provision has been made for an additional turbine and additional high pressure boilers. These turbines exhaust steam at a pressure of 150 lb. per sq. in. and 100 degrees superheat which is used for process. Further, an excess of the 625 lb. per sq. in. 750 degrees steam is provided over that required for turbine operation, which is taken to a pressure reducing station and reduced to the plant medium pressure,



* Presented at the January 27, 1936, Meeting of the Cleveland Section of the AMERICAN WELDING SOCIETY.

† Mechanical Engineer, Thomas E. Murray, Inc.

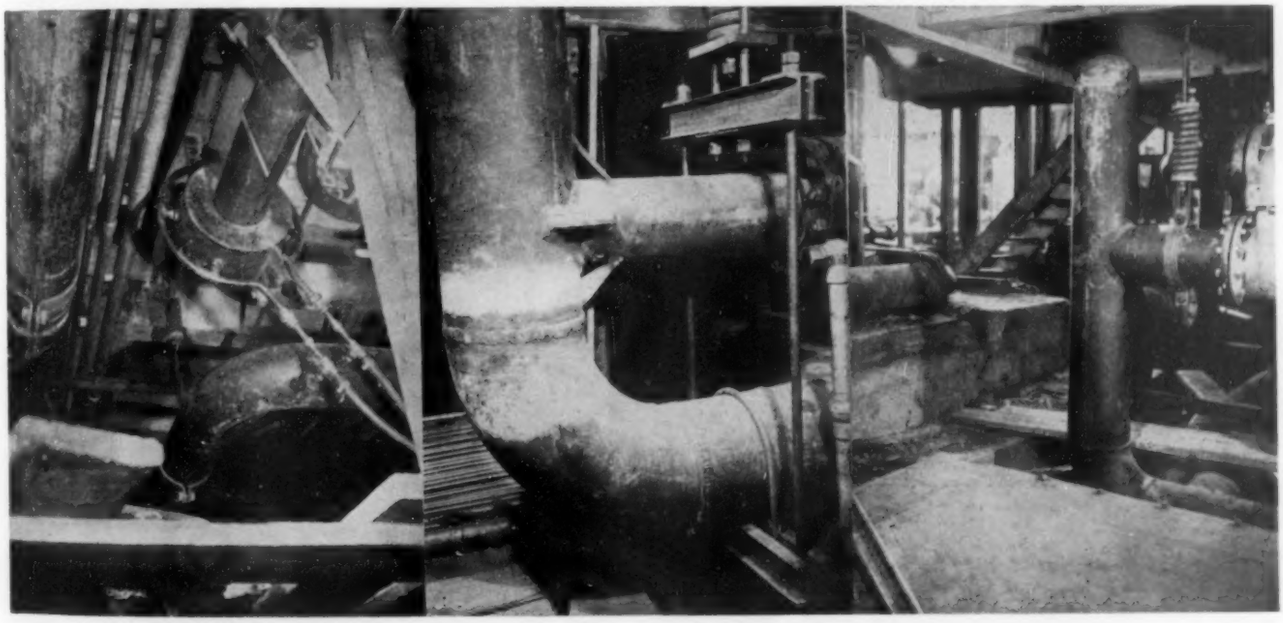


namely, 150 lb. per sq. in., 100 degrees superheat. This medium pressure steam is used for process and heating at both the Alcohol and Chemical Plants. These pressures and temperatures are not high in the light of modern central station practice but they are relatively new in the field of industrial plant operation. All piping in these various systems from 2 in. standard weight to 14 in. O.D. $^{11}/_{16}$-in. wall Grade A seamless tubing has been gas welded.

This work has started early in the Fall of 1934, just about the time peak production on anti-freeze alcohol was beginning. It was necessary therefore that this work be carried forward with a minimum of interference to plant operations. It was decided to recondition the old boilers at the Chemical Plant and use them during the construction of the new high pressure plant and later as stand-bys. In making room for the new boilers at the Alcohol Plant, it was necessary to dismantle six boilers, half of their capacity. To supply the steam required at the Chemical Plant, a twelve-inch steam line was run between the two boiler plants.

This steam line, while nothing extraordinary in diameter or length for a welded pipe lime is something of record in many other respects. It consists of 8400 feet of $12^{3}/_{8}$-in. O.D. $^{3}/_{8}$-in. wall lap welded Bethlehem Steel pipe. More than 2000 feet of this pipe was erected and welded in steel structures 30 to 60 feet in the air. The line traverses filled marshes, crosses state highways, city streets and a large railroad freight yard. Where the line ran near the ground it was supported by pipe hangers on wood piles driven in the ground. The problem of drainage on this line was complicated by the fact that for the first several months of its operation the line would carry steam in one direction and later in the opposite direction. This same condition would exist if it were necessary to shut down the high pressure boilers at the Alcohol Plant and use the standby capacity at the Chemical Plant.

Work started on this line around the first of October and steam was in the line about the middle of November—a period of about six weeks. Welding on this line was accomplished by the Gas Welding Process and the backhand technique. The specifications for welding, testing and welding operator qualification were written by the Applied Engineering Department of the Air Reduction Sales Company. Each welding operator employed on this line was required to make a position weld on $12^{3}/_{4}$ in. O.D. $^{3}/_{8}$-in. wall pipe. From this sample, eight test coupons were removed; two coupons from the top, four from the sides, and two from the bottom. Two of these coupons were tested in tension, two by the free bend method, two by the reverse bend method and two were given the nick break test. A total of four operators were tested and qualified for this work. Two of these operators worked for but a few weeks in the early stages; most of the welding was accomplished with two operators. Daily weld production averaged 10 to 12 per 8-hour day where the line runs near the ground. A few "high days" showed 15 and 16 welds. In the structure, production fell to 7–10 welds per day due principally to extreme cold weather and high winds. The difficulty of



Six-Inch High Pressure Line Weld Being Stress Relieved

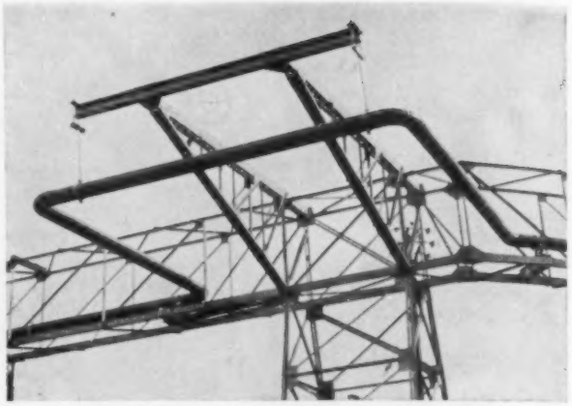
Fourteen-Inch High Pressure Line Down Lead from Boilers—Eight-Inch Tee to Reducing Valve

Fourteen-Inch by Fourteen-Inch by Ten-Inch Medium Pressure Tee

working in the steel work probably contributed to the lowered production. These figures included the so-called rolling and position welds and further each operator lined up and tacked his own joints.

Before "tying-in" the line was blown down several times with live steam to remove scale, dirt and foreign substances. In performing this operation on one section, the steam was fed too fast with the result that the water pocketed momentarily subjecting the line to severe shocks. The action was very close to that of a "water hammer" but fortunately did not reach that magnitude. The line could be distinctly seen to whip and sway. At one of the vertical expansion loops the pipe was lifted off the roller supports and crashed down again with sufficient force to shear off a 2-in. shaft on the cast steel roller and crack the base. Through all this, no failures developed in the pipe or welds. When the line was completed it was subjected to a test at full steam pressure. The idea of hydrostatically testing the line was abandoned due to the cost of filling a pipe of this size and length with water and also because of the extremely cold weather. The finished line containing 496 12-in. line welds, 16 6-in. tee or nozzle welds, besides numerous smaller welds, did not develop any leaks or failures under full steam pressure test. After a year in service, this line is giving thoroughly satisfactory service.

The line is covered with 3 in. of Philip Carey 85 per cent magnesia insulation and joints cemented with asbestos cement. The outside weather protection consists of heavy tarred building paper with 4-in. lapped joints



A Cantilever-Type Truss for Horizontal Expansion Loop Which Is Carried on the Overhead Steel Structure. Loop Is Made up of Welding Elbows and Straight Lengths of Pipe

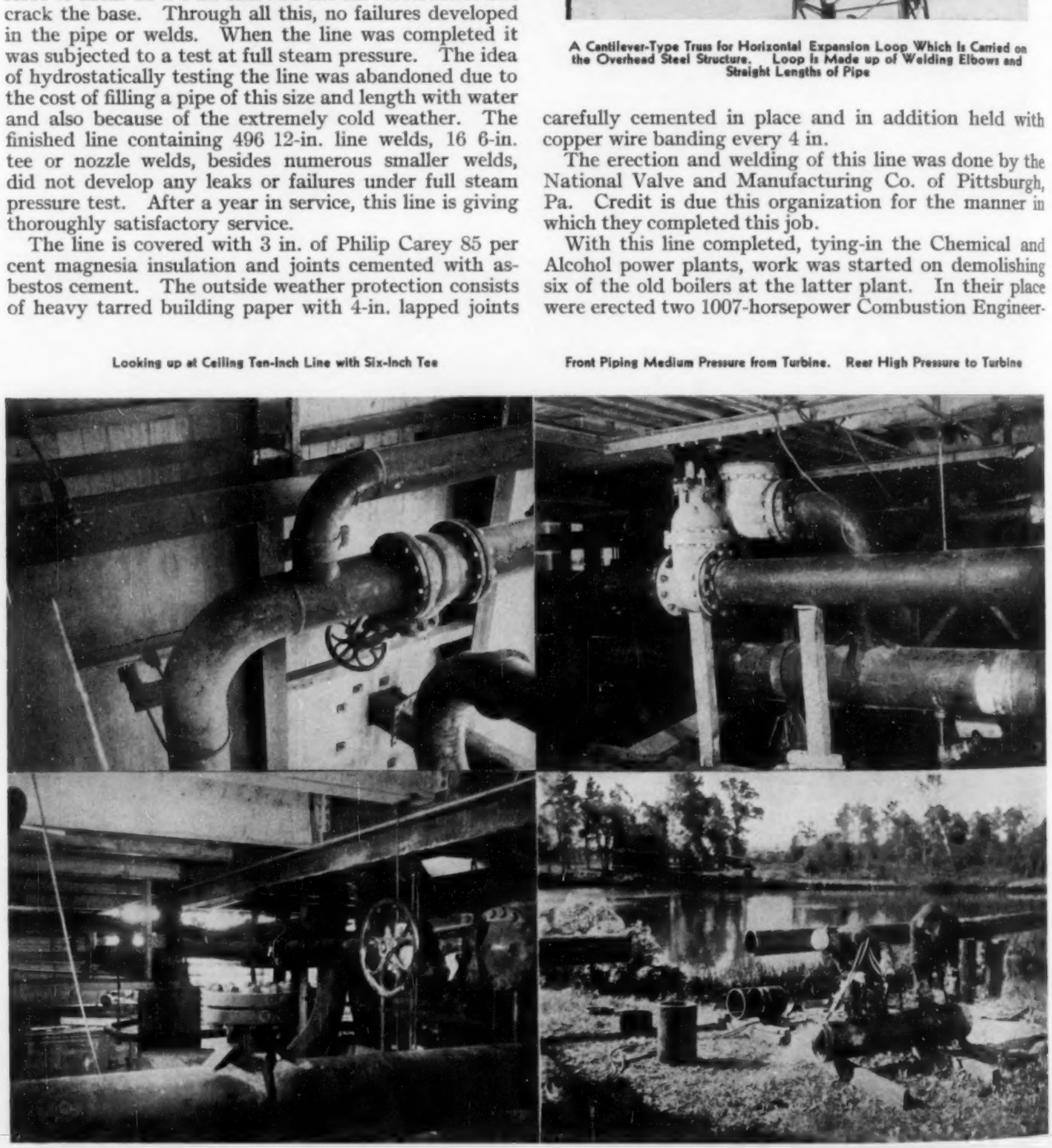
carefully cemented in place and in addition held with copper wire banding every 4 in.

The erection and welding of this line was done by the National Valve and Manufacturing Co. of Pittsburgh, Pa. Credit is due this organization for the manner in which they completed this job.

With this line completed, tying-in the Chemical and Alcohol power plants, work was started on demolishing six of the old boilers at the latter plant. In their place were erected two 1007-horsepower Combustion Engineer-

Looking up at Ceiling Ten-Inch Line with Six-Inch Tee

Front Piping Medium Pressure from Turbine. Rear High Pressure to Turbine



Fourteen-Inch High Pressure Line with Eight-Inch Tee for Future Turbine

Cutting and Beveling a "Dutchman"

ing Company's pin tube water wall, bent tube boilers equipped for either powdered coal or oil firing.

The power and other piping for this installation were designed in accordance with the American Standards Association, Code for Pressure Piping, the American Tentative Standard of which has just been published. Since this code was not generally available the specifications for this work were necessarily very detailed. The welding specifications for this piping were again written by the Applied Engineering Department of the Air Reduction Sales Company and followed closely the above Code. One deviation merits mention here and involved the substitution of one test weld for the two required in the Code. Since 14-in. O.D. Grade A seamless tubing $^{11}/_{16}$-in. wall thickness was the largest size to be used and further, since much of this pipe would be position welded, it was decided to make the qualification test weld a horizontal position pipe weld on this large size. A total of five welding operators were qualified on this test.

Multipass gas welding was employed on all the high pressure piping while single pass welding was used on the medium pressure piping. The use of Multipass welding on heavy wall pipe insures better quality welding. All welds in the high pressure piping four inches in diameter and larger were stress relieved by heating to 1450° F. and holding at this temperature in the ratio of 1 hour per inch of thickness.

The fact that as much of the old equipment as possible was required to be kept in operation, to take care of the peak production, necessitated the removal of the old equipment and installation of the new together with the necessary building alterations in several steps.

The new boilers were installed in one end of the old boiler house. The old steam main ran the full length of the boiler house with connections to the plant at both ends. It was necessary to keep this main in service until the new pipe lines had been installed and while alterations to the building and steel work were being made. In some cases the supporting steel was removed and temporary supports installed. Any disturbance of the line resulted in leaks at the joints showing the weakness of flanged connections and the wisdom of using welded connections whenever possible in the new installation.

The overlapping work such as removal of old equipment, making the necessary building alterations and keeping the plant in operation resulted in considerable congestion and in order to expedite the piping work as much as possible, most of the piping was fabricated including the welding of ells, tees and nozzles to the pipe, at the piping fabricator's plant.

Much of this piping was fabricated into convenient shipping lengths at the piping fabricator's plant. All welds in such prefabricated piping were stress relieved at the shop. As a consequence of this procedure, practically all field welds were position (both horizontal and vertical) welds and naturally progress was slow. All field welds in high pressure piping were stress relieved with portable furnaces using liquefied petroleum fuel gas and compressed air. This method proved very satisfactory for this work.

The entire power piping system was tested hydrostatically, the specifications calling for $1^1/_2$ times normal working pressure. The high pressure piping was tested at about 1075 lb. which was about 100 lb. per sq. in. above the required test pressure of 975 lb. ($1^1/_2$ times 650 lb. per sq. in.). Under this pressure, each weld was hammered hard with a 5-pound hammer and no leaks or failures were discovered. The medium pressure piping was tested at 225 lb. per sq. in. ($1^1/_2$ times 150 lb. per sq. in.) and no leaks or failures discovered. The fact that under test and during four and one-half months of operation no leaks or failures have developed, speaks well for the welding done here.

One of the objections usually raised to the use of welded joints in piping systems is the fact that alterations cannot be made without cutting the pipe. I do not feel that this is a serious objection as any large industrial plant should have a competent welder available and alterations can be made much quicker by the use of welded joints and welding fittings, particularly in the larger sizes where the pipe must be prefabricated, if joints are used. Even a slight error in measurements with prefabricated flanged pipe will lead to difficulty in making the change whereas if welded joints are used, the pipe can be cut on the job.

The use of welded joints lends itself more readily to the proper supporting and anchoring of the pipe as when all welds are made the system is one continuous structure without any weak spots, and much lighter in weight whereas every flanged joint is a weak spot in the piping structure when considered from the standpoint of supports and anchorage.

Expansion can be more easily taken care of by the use of bends made up of welding ells and straight pipe than with the conventional expansion bend.

Now that the complete system is in operation the plant engineers are well pleased with the performance and operation. The actual condensation losses of the outdoor steam line have been quite close to the theoretical losses which we calculated when the line was planned. Everyone concerned in the construction of this system is thoroughly convinced that welding is by far the most desirable method of joining pipe for steam and other services. In fact, I would hardly care to think of this type of system installed with the old type flanged and screw joints.

The design, supervision and inspection of the project was carried on by our organization, Thos. E. Murray, Inc. The qualification of welding operators and the inspection of welds was done by the Applied Engineering Department of the Air Reduction Sales Company.

Opening Remarks for Session on Piping and Pressure Vessels*

By D. S. JACOBUS†

THE subjects to be covered in the papers to be presented are of great importance to the welding industry. The use of fusion welded pressure vessels has grown apace during the last five or ten years. It took a long time for fusion welding to come into its own, or, perhaps, it would be best to say, to reach its present state of development. We have now reached a point where practically all boilers built for central power plant service have fusion welded steam and water drums and where the same applies to pressure vessels of all sorts and descriptions. The practice of welding steam piping is not as general as it is bound to be in the future. The coming steam power plant will, beyond a doubt, be one in which all the piping is welded except at joints provided for detaching certain parts, such joints being limited to the smallest number that can conveniently be used; in many cases detachable joints will be abandoned where

* Meeting of International Acetylene Association, Cleveland, Ohio, November 14, 1935.

† Advisory Engineer, The Babcock & Wilcox Company, and Past-President, AMERICAN WELDING SOCIETY.

it is feasible to cut the piping apart when necessary and reconnect it by welding.

Some have asked why we are not making more rapid progress in reaching the final goal. As I see it, we are progressing as rapidly as is consistent with the best interests of our profession. There are still unsolved problems such as the effect of the stresses due to the welding. In the case of unfired pressure vessels and boiler drums, the residual stresses can be removed by stress-relieving in a heating furnace to a point where they will not give trouble in service. Stress-relieving by placing the complete structure in a furnace cannot be done in the case of piping except for individual disassembled sections, nor can it be done in many other constructions, and the method of handling residual strains produced by welding is one on which many are working and on which there are wide differences of opinion. There are many other problems involved, such as in welding alloy steels and non-ferrous materials. By all of us working together along conservative lines we can hasten what we are sure will be the final outcome. We should not, however, allow our success to blind us to the necessity of proceeding along the sound and careful lines that have characterized our advance in the past, bearing in mind that we are dealing with structures where a failure may mean disaster and where it is much better to be safe than sorry.

Welded Piping and Pressure Vessels in the Marine Field*

By JAMES W. WILSON†

THE trend to higher pressures and temperatures in the marine field is ever increasing, the highest pressures on American vessels now in operation being 450 lb. per sq. in., the total temperature ranging from 700 to 750° F. Recently, designs were approved for an installation operating at 550 lb. W. S. P. and a total temperature of 800° F. One of our leading shipyards is now working on designs for a ship which is intended to operate at 1200 lb. W. S. P. and a total temperature of 850° F., hence the necessity for improved methods of fabrication in which fusion welding seems destined to displace existing methods of construction.

Welded boilers and pressure vessels have been approved by the Bureau of Navigation and Steamboat Inspection for the past year, several boiler installations have been made and are operating successfully. No difficulty has been experienced in their manufacture or operation, and no work has had to be rejected. Moreover, a number of welded unfired pressure vessels, such as fuel oil and feed water heaters, evaporators, separators, etc., have been installed, and it is gratifying to note that, as in the case of the boiler, no difficulty or defects have been detected. The record to date reflects great credit upon the manufacturers of such equipment for their cooperation in endeavoring to furnish dependable products. From my experience, I have no hesitation in saying that the shipowners and shipbuilders who have pioneered in the introduction of welded equipment in the marine field are very enthusiastic about its performance under service conditions, and in my contact with them I am advised that when new equipment is ordered, welded construction will be specified. All of the boilers and pressure vessels referred to were constructed in accordance with the requirements of the Welding Code of the Bureau which was developed by a sub-committee of the Committee on Welding in Marine Construction of the AMERICAN WELDING SOCIETY. At the present time there is an insistent demand and urgent need for extending this Boiler Code to include high pressure piping, that is, piping subject to boiler pressures and temperatures. The Code as it now stands permits welded piping for 100 lb. per sq. in. only. The successful use of welded boilers and pressure vessels, together with the fact that experimental work has been done along these lines, seems to justify the development of a code for the welding of high pressure piping in position on shipboard. The Committee on Welding in Marine Construction is at present giving this matter careful thought and study, and in the near future meetings are to be held to attempt to get together on a safe and dependable code. It is perhaps the most difficult problem which this Committee has had to solve as yet, and upon the success or failure of such a code will depend to a great extent the future of the art of fusion welding in the marine field.

It is a fact that many large power stations ashore are operating successfully with welded piping on heavy pressure lines, but one point that cannot be ignored is that marine piping is subjected to a harder usage than is piping in stationary plants. All marine engineers will agree on this point, for not only are there the usual stresses of pressure, temperature, expansion and contraction and vibration to contend with, but also the indeterminate stresses placed upon the piping due to the pitching and rolling of a vessel in a seaway, which impose severe twisting, buckling, bending and pulling stresses, or to the impact resulting from a grounding of a vessel. Therefore, the subject is one that must be approached with extreme caution. Another difficulty to be dealt with is the fact that two of the major safeguards of fusion welding have to be sacrificed in its application to piping, namely, the X-raying of the welded joints to determine their soundness, and the stress-relief of the piping under ideal conditions in an annealing oven.

The only precedents covering the use of welded marine piping of which I have any knowledge are the piping on

* Read at the 30th Annual Convention, International Acetylene Association, Cleveland, November 12, 13, 14 and 15, 1935.

† Engineer, Bureau of Navigation and Steamboat Inspection, Department of Commerce, Washington, D. C.

the steamship *Dixie* and on certain liners built for the Grace Line. Let us consider the case of the *Dixie* first. On October 21st I made a survey of this vessel, which recently grounded in a hurricane on French Reef in the Florida Straits, and found that, although this vessel has been in continuous service for a period of 10 years and the stresses placed upon the piping while the vessel was being pounded on the reef were terrific, nevertheless the piping remained intact; not a weld cracked, nor were there any signs of leakage or distress of the joints.

It may be well to describe briefly the type of joint used on the *Dixie*. It is a combination screwed thread and welded joint, the end of the pipe being screwed into the flange and the lip of the flange being welded to the wall of the pipe. The welding was done by the gas process and was supervised by the experts of one of the large acetylene welding companies.

The piping on the Grace Line ships previously referred to comprised the astern inlet pipes to the turbines only. These pipes were welded by the butt-weld method, some by the gas welding process and others by the electric-arc process. The welding was performed in the shop in accordance with the A. S. M. E. code requirements for Class 1 welding, it being possible in this case to X-ray the welds. This piping has been in service for about four years without trouble of any kind.

It is my thought that, in developing such a piping code, drastic qualifying tests should be prescribed for the welding operators; that special attention should be given to the selection of welding rods and that only the best quality of high test welding rods should be permitted. It might be necessary for the Bureau to establish an improved list of welding processes and procedures to insure safe welds. It should be the aim of the Committee to endeavor to secure welded joints which would have as nearly as possible the physical characteristics of the base metal. The test specimens should be welded in position without turning the pipe, welds being made vertically and horizontally. The tension test specimen should be tested in the full section of the pipe, particular attention being given to securing complete penetration. It would be most desirable if some reasonable means could be devised as a substitute for the X-rays to determine the soundness of the joints. It is my belief that all of these features will be carefully considered by the Committee and that from the study and research that has been made it will be possible to develop a safe and dependable code for the welding of high pressure piping.

Discussion by C. W. Bryan†

Mr. James W. Wilson has outlined clearly the problems connected with the use of welded piping for high pressure marine service and has indicated the Bureau of Navigation and Steamboat Inspection's intention to develop rules for its acceptance.

Designers of ship propelling machinery have long been cognizant of the operating economies available to the shipowner by use of high pressure steam. As adequate materials have become commercially available, pressures and temperatures have risen and gratifying results have been obtained. As Mr. Wilson points out, a new vessel is now under consideration with a piping system intended to operate at 1200 pounds pressure and at a temperature of 950° F. The piping in such installation will require a joint superior in tightness to any form of bolted flange connection. It is now possible to provide a welded pipe joint which will fulfill the necessary requirements and will minimize the hazards of the installations.

Marine designers and shipbuilders advocating the use of welded piping are thus faced with the problem of proving its ability to withstand the stresses and strains outlined in Mr. Wilson's paper. The problem reduces itself to a study of the following:

1—The determination of the forces acting on the pipe and joints in marine installations in order to establish the basic conditions of their design.
2—The development of standard designs of welded joints to satisfy the basic design requirements.
3—The selection of a proper welding technique and the qualification of welding operators capable of executing it.
4—The testing of the completed structure to insure that it has met with design requirements.

The AMERICAN WELDING SOCIETY'S Committee on Welding in Marine Construction has given careful consideration to the foregoing requirements and has available the assistance of the technical experts of shipbuilding and other organizations engaged in the manufacture of high pressure steam equipment. It is proposed to evolve rules that will assist the Bureau to find an assured method of securing safety in high pressure installations and thus make available to the American Merchant Marine the economies already proved.

It is quite probable that the first of these marine installations for over 1000 pounds pressure will require some destructive testing of the finished joints which will not be necessary when more experience has been gained in this work.

† Assistant to President, Federal Shipbuilding and Dry Dock Company, Member of AMERICAN WELDING SOCIETY Committee on Welding in Marine Construction.

Discussion by J. H. King†

Mr. James W. Wilson's paper on "Welded Piping and Pressure Vessels in the Marine Field" is very timely and of considerable interest. The increasing use of higher pressures and temperatures in marine work clearly indicates that further progress is needed in connection with the welding of piping and that a satisfactory code for such welding should be adopted.

Mr. Wilson suggests methods for developing a code which we believe to be thoroughly sound. While progress is needed, it should be made only after careful and thorough investigation into the numerous complex problems involved. The old adage that "haste makes waste" is quite true in work of this kind. Until more experience with welded piping is available it would seem best to adopt a very conservative and ultra safe policy in order that the whole art may not be condemned by failures.

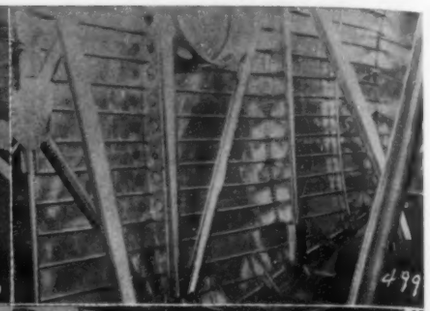
Mr. Wilson's remarks are very pertinent to this discussion and the suggestions in his paper should be given the careful attention that they merit.

† Manager, Marine Dept., The Babcock & Wilcox Co.

Shot-Welded Stainless Steel, Fabric Covered Control Surfaces (Ailerons)

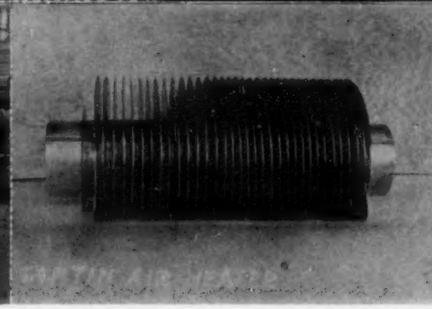
Shot-Welded Corrugated and Flat Stainless Steel Control Surface (Flap)

Interior View of Shot-Welded Stainless Steel Hull Skin and Structure

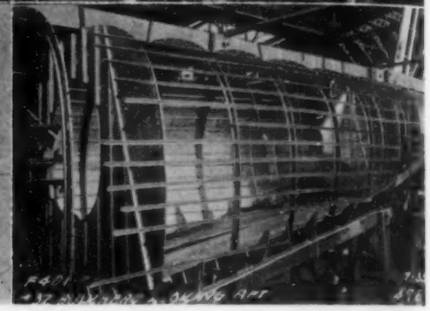


Shot-Welded Corrugated Stainless Steel Monocoque Construction Control Surface (Aileron)

Stainless Steel Flanged Fins, Seamwelded to Seamed Stainless Steel Tube Forming Air Heater



Shot-Welded Stainless Steel Hull Construction before Application of Skin



Welding in Aviation*

By CARL DE GANAHL†

I AM highly honored in being asked to talk to you tonight on "Welding in Aviation." However, I am hardly qualified to talk on so general a subject since my experience has been limited principally to one branch, that of electric resistance welding of stainless steel. I shall, therefore, have to draw on information obtained from other sources and among others I am indebted to Mr. Knerr of Metlab, Philadelphia, for considerable information.

Oxyacetylene torch welding in aircraft first came into general use during the War on built-up fittings of low carbon and alloy steels. The advantages of the process were immediately apparent. The investment in equipment was small, the flexibility in making complicated fittings was particularly convenient, and, as a result, the application of the process rapidly increased. With more general use of the process there developed the necessity for higher strength alloys, which at the same time had to have satisfactory welding characteristics. The steel that seems to have survived the test of time is chrome-molybdenum steel, containing 1% chromium and 1/4% molybdenum. It is readily welded and with proper technique is reliable. It has the advantage of a tensile strength of about ninety thousand pounds per square inch in normalized condition and as-welded, and is regularly heat treated to as high as 200,000 pounds per square inch on landing gears and similar parts. In wing beams and other parts, subject to vibration, the maximum is from 160,000 to 180,000 pounds per square inch. This is due to its higher elongation at the lower strengths and to the fact that above these figures the fatigue values do not increase proportionately.

The great majority of landing gears today are built of torch-welded chrome moly. tubing heat treated, and for a number of years it was almost standard for fuselage construction. Similar wing spars have also been used with considerable success. The last two have only recently given way to monocoque stressed skin construction, where the torch is not so convenient. Torch welded chrome moly., however, will have its place in aircraft construction for many years to come.

Torch welding of aluminum and some aluminum alloys has also been accomplished successfully. It has, however, been fairly limited to gasoline, oil and water tank construction.

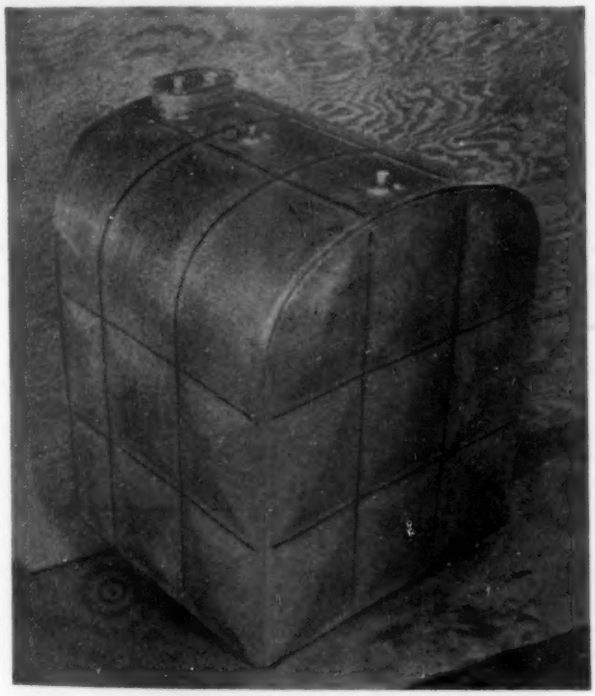
Electric arc welding of alloy steels has been tried with some degree of success but has not come into general use because of the increased time necessary to train personnel, difficulty of control when welding very thin sections, and probably as much as anything, due to the presence of an already satisfactory and easier process, that of oxyacetylene torch, as already discussed.

Electric resistance welding of chrome molybdenum was tried but without success. The difficulty was that the almost instantaneous cooling following fusion temperature caused a brittleness of the spots which required subsequent heat treatment before sufficient ductility could be obtained. It was then found on complicated structures that a considerable portion of the spot welds were lost during the best heat treatment before normalization. Our conclusion, therefore, was that spot welds on chrome moly. were too brittle to be of use without

* Presented at the December 17, 1935, meeting, New York Section, A. W. S.
† President, Fleetwings, Incorporated.

subsequent heat treatment, and that too serious a loss, due to breakage of spot welds, occurred during heat treatment. The process was therefore abandoned.

Chrome moly. steel, unfortunately, is not corrosion proof. Corrosion has always been a nightmare to aircraft operators because structures are of necessity so light that they have only the minimum margins of strength and, therefore, comparatively thin metal is the rule. Corrosion, therefore, impairs the strength below the limits of safety much more rapidly than on normal structures where the metal sections are so much thicker. Corrosion protection, therefore, is a serious consideration. The method at present in use for protecting chrome moly. parts is generally that of sand blasts, cadmium plating and then painting. The inside of closed tubing, however, offers a more difficult problem and the method in common use is to pump hot boiled linseed oil or the equivalent into the tubes through eighth-inch holes at each end. After draining the holes are closed by small drive screws. Fair protection has been obtained for ordinary use, but it is not adequate against salt air or salt water exposure.



Seamwelded Stainless Steel Tank

Stainless steel offered an excellent solution to the problem but when it first became available did not prove so attractive to aircraft manufacturers because of its low yield point, around 35,000 to 40,000 pounds per square inch in annealed state, with an ultimate tensile strength of 80,000 to 90,000 pounds. It was, however, tried in places where high strength was not required and corrosion resistance was of importance, such as exhaust manifolds. These were torch welded. The results at first were not satisfactory because the torch welding raised the temperatures of the stainless through the critical range where carbide deposition occurred, and intergranular corrosion and consequent failure resulted.

When, however, hard rolled high tensile material became available its high physical characteristics immediately attracted our attention. Material can now be obtained with tensile strength of 185,000 pounds per square inch, yield points above 150,000 pounds per square inch and elongation of 15 to 25%. At last, here was a material with high physical characteristics, with excellent resistance to corrosion. How would it weld, however?

Unlike chrome moly., sudden chilling from a high temperature anneals the material and shot-welding proved an excellent method of fabrication. Ductile spots can be reliably obtained from 80 pounds to 15,000 pounds per spot depending on the thickness of material used. We have continued the development of this art and in the course of time have built welding machines of an entirely automatic character, some of them capable of delivering 960 shots per minute. We are at present fabricating many aircraft parts of high tensile stainless shot-welded.

In the meantime, however, the steel companies have gone to work on remedying the difficulties encountered in torch welding. It appears that the intergranular corrosion and failure caused by torch welding was due to deposition of chromium carbide within certain temperature ranges, along the crystal faces, leaving the crystal faces poor in chromium, which rendered the material subject to corrosion along these paths. By the addition of titanium or columbium to the steel the carbon is taken up as titanium or columbium carbide preventing interference with the chromium, and 18-8 steels are now available containing one or the other of these two elements which can be subjected to any range of temperature up to 1600 or 1700° F. without any loss in corrosion resistance.

Torch welding the titanium bearing steels offers one difficulty due to the fact that the action of the torch tends to burn up the titanium and its absence is noticeable in the weld metal. Columbium strangely does not have this characteristic and satisfactory results are obtained if either titanium or columbium bearing stainless steels are welded with columbium bearing rods. Exhaust manifolds of 18-8 stainless steel containing titanium or columbium are now almost standard with the Navy and the Army Air Corps.

As mentioned before, we are fabricating many aircraft parts of high tensile 18-8 stainless by shot-welding methods. These are corrosion resistant and eminently satisfactory. There are, however, a great many places where torch welding on the high tensile material would be a tremendous convenience and facilitate fabrication materially. It is hoped, therefore, that the steel companies will now make high tensile stainless steels available for us that contain titanium or columbium.

Looking into the future application of stainless steel in the aircraft industry it is necessary to answer one particular question "How does its weight strength ratio compare with the materials at present fashionable?"

So far our data indicate that we can build parts in stainless as light and frequently lighter than in other materials. The larger the parts called for and the higher the stresses the more advantageous the use of steel. The reason for this is that in small parts it is necessary to use minimum gages, where sometimes even then the strength is above that required, and the parts are inclined to be fragile. Where high stresses are the rule, thicker gages can be used and full advantage of the high physicals can be taken. The larger the airplane, therefore, the more suitable the use of stainless becomes. Stainless steel is therefore well suited to the building of large aircraft, where its resistance to corrosion and high permanent physicals give it a distinct advantage.

In large aircraft the investment sometimes reaches $1,000,000 and more and obsolesence in three to five years, which is the rule at present, is intolerable. With the necessity for increased useful life, corrosion resistance becomes of increasing importance both from the point of view of maintenance and long life.

Fig. 1—Boom in Early Stages of Construction

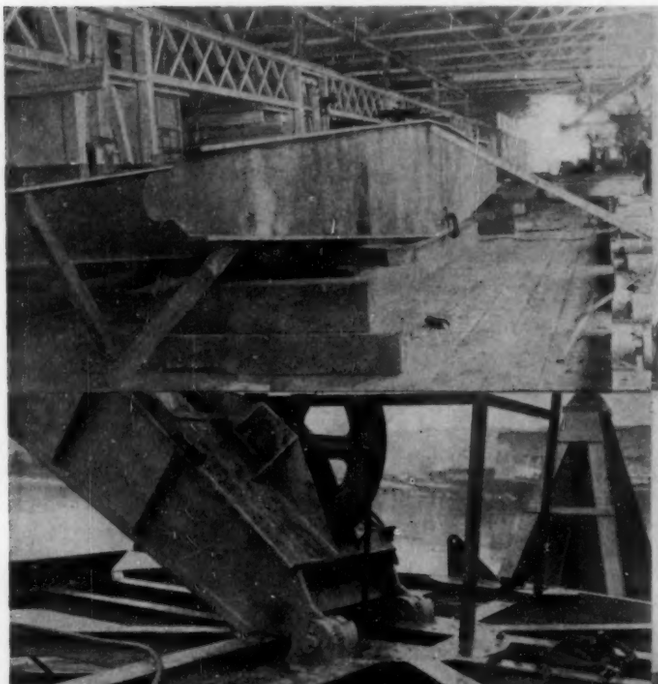


Fig. 2—Upper End of Boom

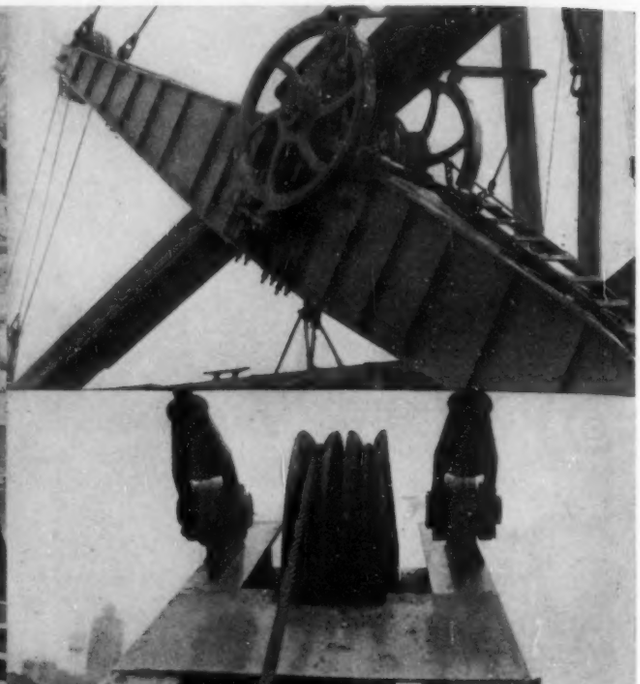


Fig. 3—Lower End of Boom

Fig. 4—Sheaves and Cable Connections

Arc Welding Used in Dredge Reconstruction

By A. G. BISSELL†

UNDER the direction of Mr. H. W. McCurdy, President, the Puget Sound Bridge & Dredging Co. recently rebuilt the dipper dredge *Everett*, installing new steel spud casings and "A" frame pedestals, "A" frame, boom, bull wheel, kick-backs, dipper and handle and much other apparatus. In all of this work arc welding was extensively used in the fabrication of the steel parts.

The largest single section to be fabricated by arc welding is the boom. This boom, 48 feet in length and $4\frac{1}{2}$ feet in depth, is composed of two fabricated plate girders. These girders in an early stage of their construction are shown in Fig. 1. Here are shown the $\frac{3}{8}$-inch plate webs and the 1 in. x 8 in. flanges as assembled before the 1 in. x 3 in. stiffeners were added. The upper end of the boom, the gear and dipper handle are shown in Fig. 2. The lower end and its connection to the bull wheel are shown in Fig. 3. In both of these views the simplicity of the boom construction is evident. The absence of angle connections is most noticeable. It is estimated that this boom is about 16% lighter than one of riveted construction. The boom tip, showing the sheaves and cable connections, are shown in Fig. 4. It can be seen that a portion of the girder web plate is extended through a slot in the top flange to form the connection lug. One and one-half-in. pads attached to each side of the lug give sufficient bearing for the connecting pin. Three-fourth-in. plates were added to each side of the extended web lug and a triangular plate on the outside to increase the lug's rigidity. The lugs at the base of the boom are similarly reinforced.

The bull wheel has a channel rim and H section spokes united with a plate center to form a one-piece unit.

The "A" frame pedestals are an integral part of the spud casings. The "A" frame legs are constructed of two 15-in. 33.90-lb. channels, a $\frac{3}{8}$ in. x 14 in. plate and $\frac{3}{8}$ in. x 3 in. strap lacing.

The dipper handle consists of two 10 in. x 16 in. fir timbers encased in $\frac{3}{8}$-in. steel plates arc welded to form solid casings to which are bolted the cast steel racks.

In the engine room of the dredge arc welding has been used in the construction of engine bases, brake gear, levers, sheave housings, etc. Two lattice girders extending across the barge and supporting the deck under the bull wheel were fabricated in place by arc welding with a saving of material and construction time. In fact all new construction except a very few castings was fabricated by the arc-welding process.

The major parts were fabricated by the Wallace Bridge & Structural Steel Co. and The Isaacson Iron Works of Seattle, Washington. All design and erection work was done by the Puget Sound Bridge & Dredging Co. The author was the consulting welding engineer.

† Consulting Engineer, Arc Welding Engineering, AMERICAN WELDING SOCIETY.

The Micro Testing Machine Chevenard*

UP to recent times tension test of materials was performed only on large, heavy, bulky testing machines, necessitating the machining of heavy specimens. Under these conditions the systematic study of the metals and alloys was made at a very high cost.

It was impossible to closely investigate a finished piece and to control at various spots its mechanical properties by means other than the hardness test, which apparently is unsatisfactory.

The need was felt for an apparatus permitting the use of small specimens (a few millimeters), weighing fractions of grams, costing very little, and which could be easily taken off from the fabricated pieces without destroying them.

The desired apparatus has recently been designed and built by Chevenard, for the use of research men. This testing machine intended to perform common mechanical tests on very small specimens, is of particular interest to welders because the deposited metal in fillet welds can hardly be used in the preparation of large specimens. For the study of welds, the micro testing machine fills a need.

The micro testing machine has been designed to perform tensile, shear and bending tests. It photographically records corresponding diagrams for these three tests, which means, respectively: strain-stress diagram in tension, strain-stress diagram in shear, stress-deflection diagram in bending. In order to understand the operation of the testing machine, a tension test is studied.

The tension specimen has both ends threaded for 7 mm. or $^1/_4$ inch in length, and is 1 to 1.5 mm. or $^1/_{32}$ to $^1/_{16}$ inch in diameter. Both ends are screwed on small heads having a sphero-cylindrical shape.

One end of the piece slides in a groove at the end of lever L and the other end into an identical groove in the cantilever plate R. The lever rotates around a perpendicular axis to the plane of the figure, and moves in the direction of the arrow by means of a small electric motor. This motion stresses the specimen. Spring R, in Elinvar[1] and working at a low load, forms a faithful and accurate dynamometer. (Figs. 1 and 2.)

The load-strain diagram is recorded on a photographic film by a ray of light. The vertical displacement is proportional to the displacement of the cantilever plate R, that is, the load on the specimen. The horizontal displacement is proportional to the difference in displacements of lever L and the cantilever plate R, that is, the elongation of the specimen. This result is obtained by reflecting a fixed ray of light on a small mirror fixed on an optical tripod adjusted in the following manner:

The tripod is made of a plate of invar, supported by three points in heat treated steel p_1, p_2, p_3, forming a rectangular triangle (Fig. 3).

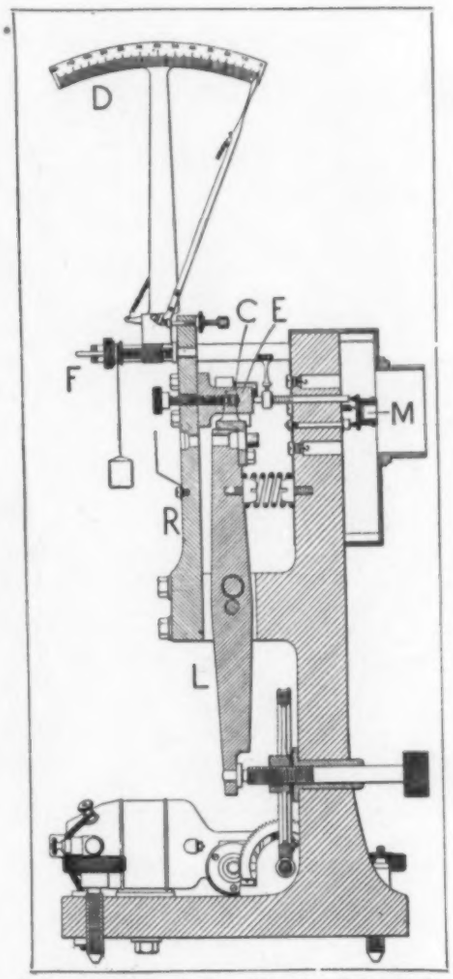


Fig. 1—Vertical Cross Section of the Micro Testing Machine

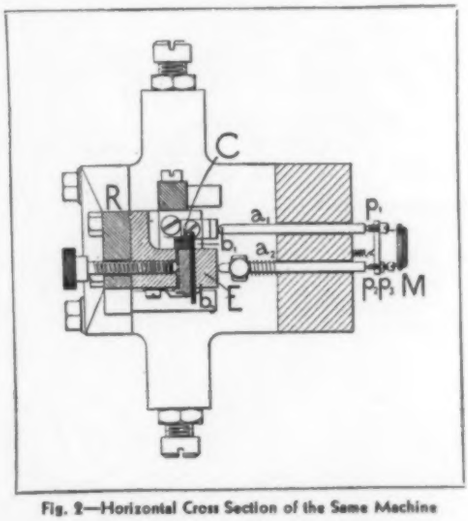


Fig. 2—Horizontal Cross Section of the Same Machine

1—For p_1, the end of a rod that freely slides horizontally through lever L, and is fixed on the cantilever plate R, so that any movement of the plate R is detected.

2—For p_2, the end of a second rod that is maintained in contact with lever L.

3—For p_3, a fixed point on the frame of the testing machine.

At a definite moment of the test, the moving points occupy positions p_1 and p_2, the test continuing, they come at another instant to occupy positions p_1', and

* This article was originally published in French in *Soudeur Coupeur* (10, Nov. 1935, pp. 9–10, ill.), and was translated by Mathew Scioletich (assistant to the Welding Research Committee of the Engineering Foundation). The translator took the liberty to include additional information from *Comptes Rendus de l'Académie des Sciences* (T. 200, Jan. 14, 1935, pp. 212–215), and *Revue de la Soudure Autogène* (27, Feb. 1935, p. 6). A contribution to the Fundamental Research Committee.

[1] *Elinvar*—Ferrous alloy 36% Ni, 12% Cr, 0.8% C, 1 to 2% Si, traces of Mn, S, P. Ultimate strength in tension 75,000 lb. per sq. in. Elongation 30%. This alloy has a very small coefficient of expansion.

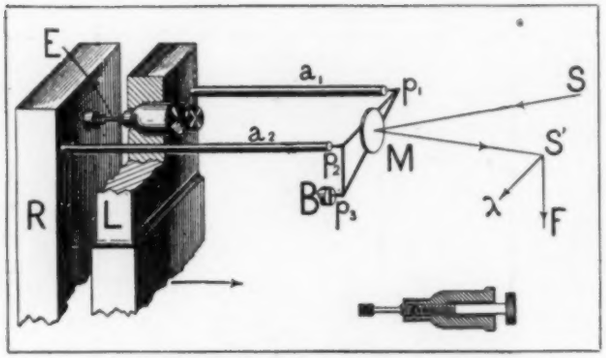


Fig. 3—Micro Testing Machine. Layout for Tension Test

p_2', the displacement p_1p_1' being greater than the displacement p_2p_2' (the difference being the elongation of the specimen). The change of position of the two points can be divided into two stages:

1st Stage.—p_1 changes position at first at the same rate as p_2, the line p_1p_2 therefore moves parallel to itself. The tripod inclines and its inclination is the same as though it had turned around a fixed horizontal hinge p_1p_2, while the point p_3 would have moved in the opposite direction, by an equal displacement. In this manner, in the first stage, the ray reflected by the mirror moves in a vertical plane at an angle proportional to the displacement of p_2 which corresponds to the displacement of the cantilever plate R, in other words, the load on the specimen.

2nd Stage.—p_2 being maintained fixed, p_1 completes its displacement. The tripod then turns around the vertical hinge[2] p_2p_3 and the reflected ray moves in a plane perpendicular to the hinge p_2p_3, in other words, in a horizontal plane. The angle covered horizontally by the ray of light is proportional to the displacement p_1, and therefore to the elongation of the specimen.

Figures 1 and 2 show the layout of the machine. Besides the mentioned parts, dynamometer D and brake F may be seen.

This brake aims to oppose some resistance to the sudden release of the spring after failure of the specimen, which may damage the apparatus. The dynamometer shows at any time during the test the load on the specimen.

For shear test (Fig. 5) a round bar specimen 1.5 mm. or $^1/_{16}$ in. in diameter is used. This specimen is rigidly fixed in a vice carried by the cantilever plate R. It is sheared by a knife C fixed at the end of lever L, and the edge of which moves very closely along the side of the vice. The coordinates of the registered curve are

[2] The displacements of p_2 being always very small with respect to the distance p_2p_3, we can assume that the hinge p_2p_3 stays vertical.

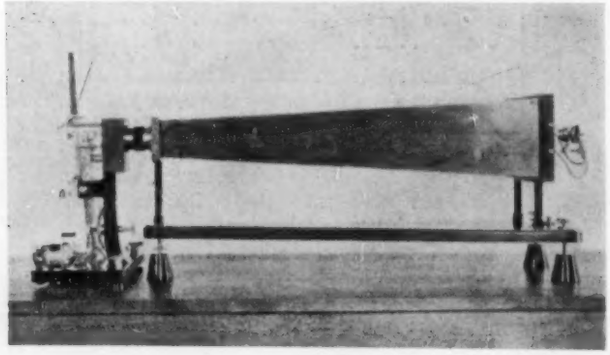


Fig. 4—Micro Testing Machine

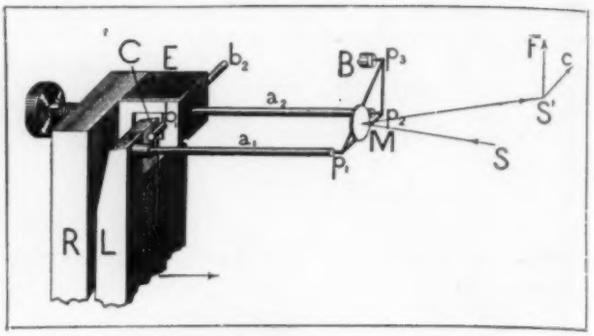


Fig. 5—Micro Testing Machine. Layout for Shear Test

the shear deformation C of the specimen and the shearing load F.

In the same manner, the diagram of the micro bending (Fig. 6) has for abscissa the deflection of the specimen Ec, cylindrical or prismatic in cross section, and for ordinate bending load F.

The dimensions of the specimens are exceedingly small (7 mm. or $^1/_4$ in. long and 1.5 mm. or $^1/_{16}$ in. in diameter). This is an important factor in economy, especially in the study of the variation of mechanical properties of alloys with different chemical compositions.

The smallness of the specimen easily allows the selection of samples to be tested from the finished pieces, thus during machining small rejected pieces may be used to prepare micro specimens.

Particularly in the case of welded joints samples at critical spots may be taken and the hole or groove can be plugged by welding.

The micro shearing test is particularly important in the mechanical investigation of welded pieces. A small rod of metal is taken in a vertical direction to the line of weld. Later it is cut in short pieces by the machine, which records for every section the shearing force necessary to move the knife. The sections being less than 2 mm. or $^1/_{16}$ in. apart, the micro testing machine can show in detail the variation of the mechanical properties according to a given direction in the inside of the weld. This micro testing machine has for some time been in operation at the "Office Central de l'Acetylene et de la Soudure Autogène" in Paris.

The two figures, 7 and 8, are given as an example. They illustrate the oxyacetylene welding of two plates 10 mm. or about $^3/_8$ in. thick, in chromium-molybdenum alloy steel (0.15% C, 0.9% Cr, 0.2% Mo). The diagrams of shear (Fig. 7), and of tension (Fig. 8), show in the heating zone a self-hardening with increase in the elastic limit and ultimate strength.

In the molten zone there is a hyper-quenching dis-

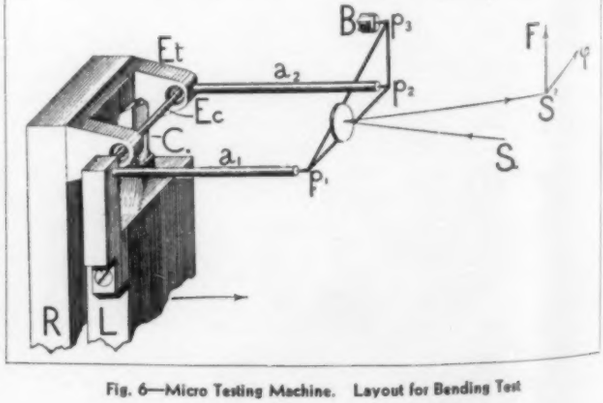


Fig. 6—Micro Testing Machine. Layout for Bending Test

tinguished by a fall of the same characteristics. There is also a decrease in elongation, the structure of the molten metal being less regular than that of the forged metal. Outside of the heated zone, a decrease of the mechanical resistance and an increase in the elongation prove the effects of heat treatment.

In the case of non-ductile metals, cast iron, brazing, etc., the micro bending test can replace the micro tension test.

An adequate use of the micro testing machine can give valuable information for the improvement of welded joints.

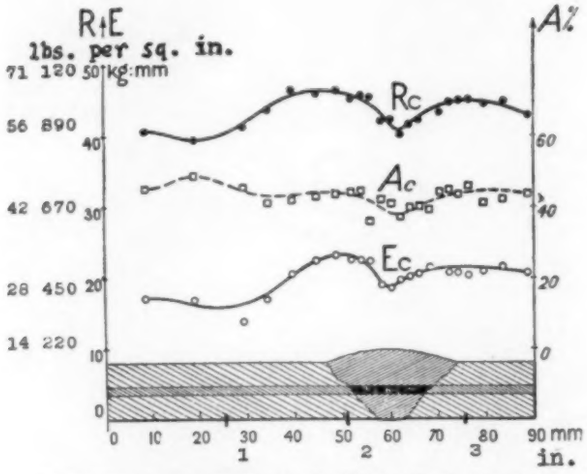


Fig. 7—Micro Shear Investigation of a Gas Weld on Cr-Mo Alloy Steel
Thickness of plate 3/8 inch.
Rc indicates ultimate strength in shear.
Ac indicates elongation in per cent.
Ec indicates elastic limit for shear.

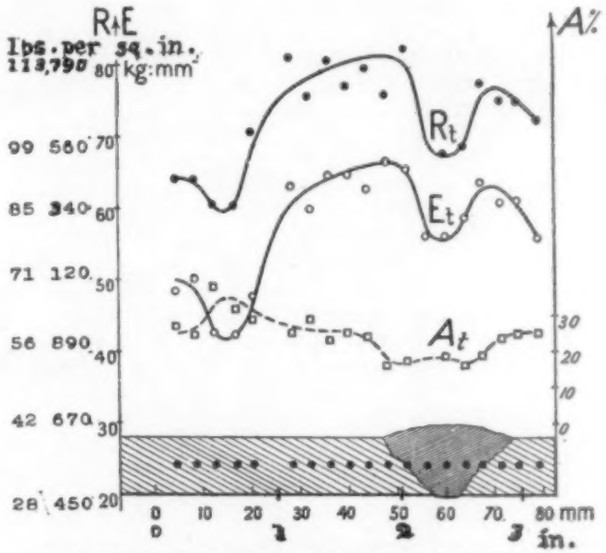


Fig. 8—Micro Tensile Investigation of a Gas Weld on Cr-Mo Alloy Steel
Thickness of plate 3/8 inch.
Rc indicates ultimate strength in shear.
Ac indicates elongation in per cent.
Ec indicates elastic limit for shear.

Progress in Welding during the First Six Months of 1935*

By W. LOHMANN AND W. SCHNEIDER

1. Effect of Material

Tests are reported by K. L. Zeyen (*Autogene Metallbearbeitung* **28,** 161–169 (1935)) on Overlay-Welding (building up surfaces) using overlay (surfacing) welding wires for gas and arc welding standardized by DIN 1913. Surfaces of one or more layers were made using St 37.11 in thicknesses of 3, 6, 15 and 25 mm. The tests with different types of flame and varying current density are notable. In gas overlay welding an incomparably higher strength is obtained with a reducing flame than with a neutral or oxidizing flame. Plate thickness has only a small effect in gas welding; the greater the plate thickness, the lower is the hardness. The above effect of the reducing flame applies only to pure carbon steel wires. The type of flame had little effect on alloyed surfaces. Opposite to the effect in gas welding, the hardness increased in arc welding; the increase was most pronounced at low currents and with carbon steel wires. The hardness increase with alloy wires was only slight as plate thickness increased and the hardness decreased very slightly with increasing current strength. The decisive factor is whether or not the first layer is allowed to cool before depositing the next. If the previous run is allowed to cool, then an increase in hardness is obtained in both gas and arc welding. As the number of layers welded on top of one another increased, the hardness also increased.

Zeyen also investigated loss by burning with the standard surfacing wire and with a manganese steel wire. Decarburization of the carbon steel wires averaged over 50%; the loss is less in gas than in arc welding. In arc welding there is a difference between A.C. and D.C. welding. With alloy welding wires the carbon loss is generally much less and is in no case greater than 50%. There is practically no loss of chromium and tungsten in gas and arc welding. Only in arc welding was there a significant loss of carbon from the manganese steel wire, while the loss of manganese was relatively slight. The greater the number of layers in the overlay, the less is the loss by burning. In this effect probably lies the explanation of the increase in hardness as the number of layers increases.

Reporting on the welding of steels of the type that are heat resistant and have good high-temperature strength, H. Schottky (*Z. VDI,* **79,** 41–46 (1935)) states that these alloys cannot be forge welded on account of their chro-

* W. Lohmann and W. Schneider, *Stahl und Eisen,* **55** (37), 991–994 and 1016–1018 (1935).
This report was translated by Dr. G. E. Claussen, research assistant to the Fundamental Research Committee. The translation is presented as a contribution of this Committee to the research workers and others interested.

mium, silicon and aluminum content but that butt resistance welding is generally applicable and is especially used for tubes. For thin sheet, spot welding is used; for thicker sheet and plate the carbon arc and atomic hydrogen (Arcatom) processes are employed. Both of the latter processes are particularly suited to mechanical tube welding. While previously the same alloys were gas welded if one of the above processes were not used, these alloys are now being arc welded. This was made possible by the production of high-quality coated electrodes without which welding of alloys with high chromium, silicon and aluminum contents would not be practicable. In gas welding a neutral flame must always be used because excess oxygen slags a part of the alloying elements and produces a weak weld, full of slag. On the other hand, excess acetylene causes carbon pick-up and, consequently, loss of corrosion resistance. Arc welding avoids these difficulties. Beyond a critical minimum thickness the arc cannot be used for fear of burning through the sheet. The advantage of arc welding lies in the fact that it produces welds with the same mechanical properties as the original material without the subsequent annealing treatment that gas welds usually require. So far as filler rods are concerned, the same composition can be used as the original material for low-alloy steels. For medium and high-alloy steels, on the other hand, it is usual to employ an austenitic chromium-nickel electrode which combines high toughness with good scaling resistance. These can be used only when it is not specified that the weld should have the same chemical composition as the original plate. Service tests have shown that no difficulties are connected with the use of such electrodes.

T. Thielemann (Dr.-Ing.-Dissert. Techn. Hochschule Dresden, 1935) has investigated the weldability of white-heart and black-heart malleable cast iron both with arc and resistance methods. Coated electrodes were used consisting of a low carbon steel core and a carbonaceous coating designed to give a weld metal containing about 3% carbon. Additions of silicon to the coating gave a weld containing about 0.9%. Welds made on both unannealed and annealed specimens showed that the white heart gave better and denser welds than the black heart. As the thickness of the casting was increased, the weldability slightly decreased. Subsequent heat treatment at 900° C. produced the same properties in weld as in original white-heart casting; machinability and toughness were also good in all cases. A half-hour anneal at 950° C., followed by a tempering treatment if necessary, is therefore recommended. With black-heart castings good properties were developed in the weld after a 2-hour anneal at 900° C., although macro-examination showed that this frequently caused blow-holes. In resistance welding the length of grip should not exceed a critical amount on account of temperature regulation.

Thielemann chose a grip length of 4.6 and 2.3 times the diameter and a compression distance of between 2 and 4 mm. The heating of the specimen was especially important because particularly in black heart, the high carbon inner zone had a tendency to melt before the outer, which caused piping and similar phenomena. Air cooling produced an increase in strength and hardness that was not accompanied by a significant decrease in elongation, toughness or machinability. Subsequent tempering caused still further improvement in the butt-welded specimens. It was found that, although a single tempering subsequent to welding did not raise the properties to that of unwelded castings, a second tempering produced the same properties as the unwelded casting. The conclusion drawn from the author's investigation is that white-heart malleable cast iron behaves better than black-heart toward arc and resistance welding.

Similar questions, especially those connected with filler rods for gas welding are dealt with by J. H. Critchett (*Metal Progress*, **27,** 27–30 (1935)).

(NOTE. This paragraph, since it summarized an accessible publication, is not reproduced.)

The next paper dealt with is by L. Ferguson (AM. WELDING SOC. JOURNAL, **14,** 18 (1935)).

2. Welding Methods

A new method of producing welded tubes is the induction method described by F. Owesny (*Röhreind.*, **28,** 49–50 (1935)). The tube, in which a laminated iron core is inserted, acts as secondary. The original design of the yoke did not limit the heat effect to the zone near the weld but, on account of the eddy current produced when the edges of the tube came in contact, the whole tube was heated. Aside from lowering the efficiency considerably, this heating during butt welding was undesirable. This disadvantage was diminished by arranging the leg of the yoke over the tube thus forming a kind of single-phase core transformer. During welding the tube again acted as secondary winding. The breadth of the heated zone, which becomes pronounced as the wall thickness decreases, is the decisive factor for welding velocity so that the more effectively the eddy currents are suppressed the higher is the welding velocity. The advantage of this method is its simplicity, and is particularly adapted for plant operation. Contrasted to the usual electric tube welding machines which have an efficiency of 20 to 30%, the above machine has an efficiency of 65%. Furthermore, the machine can be used for the so-called "Burning-off" method in which the uneven "wire" edges of the tube are burnt off by arc formation before welding; only another pair of pressure rolls is necessary.

The next eight paragraphs deal with articles written in English:

H. S. Clarke, AM. WELDING SOC. JOURNAL, 13, (9), 21–22 (1934).

C. J. Holslag, AM. WELDING SOC. JOURNAL, 13, (9), 28–29 (1934).

W. M. Brady, *Welding Engr.*, **20,** (4), 22–23 (1935).

H. A. Walker and D. S. Lloyd, AM. WELDING SOC. JOURNAL, **14,** (1), 9–10 (1935).

A. F. Davis, AM. WELDING SOC. JOURNAL, **14,** (3), 8–15 (1935).

A. P. Frugell and D. H. Corey, AM. WELDING SOC. JOURNAL, **14,** (3), 17–18 (1935).

W. D. Halsey, AM. WELDING SOC. JOURNAL, 13, (9), 11–12 (1934).

E. W. P. Smith, AM. WELDING SOC. JOURNAL, 14, (2), 21–24 (1935).

The scatter of results in the bend test is caused not only by the quality of the weld, according to *Arcos* (*Arcos*, **12,** (66), 1223–1226 (1935)), but is also influenced by the parent metal. It was shown that the higher the phosphorus and sulphur content of the parent metal, the greater is the possibility of error. However, 0.06% S may be present without noticeably changing the properties of the parent material in the vicinity of the weld. So close is the connection that the phosphorus content of a plate may be determined from the bend test of the weld made in it by an experienced welder. In this paper too much importance is placed on the injurious effects of sulphur and phosphorus in steel because the correspondents have often observed that the phosphorus content is not injurious so long as it is not excessively large, and often even facilitates welding.

3. Properties of the Weld

O. Mies (*Wärme*, **57,** 113–121 (1934) and **58,** 97–101 (1935)) has investigated the stresses in plates that have been gas- and arc-welded. Relatively large plates, about 1500 x 600 mm.^{2} were used for the investigation in order to approximate actual conditions in practice. The method used consisted of optically measuring the changes in location after welding and subsequently cutting the specimens, of reference lines drawn on the plates before welding. To locate the lines of principal stress, measurements of deformation were made at every point in three directions. The first experiments were made on plates 10 mm. thick without constraints at any point; gas welds were made in one run with 4 mm. rod; arc welds were made in three runs with 4 mm. bare electrode. The highest stresses occur in the tempered zone beyond the weld. The stresses increase greatly toward both ends of the seam and show pronounced peaks of stress at the ends of the seam. This is ascribed to the greater amounts of heat given to the plate at the beginning and at the end. The average value of welding stress calculated by Mies (20 kg./mm.^{2}) is in good agreement with that found by other correspondents, which is of the same order of magnitude. Using this average value Mies concludes that stress peaks of 30 to 35 kg./mm.^{2} exist; that is, stresses above the yield point of the material. It was also found that the lines of principal stress are considerably curved. The stresses perpendicular to the seam were much lower and were about 6 kg./mm.^{2} The welding stresses produced by arc welding were of about the same order of magnitude but the stress measured perpendicular to the direction of welding was somewhat higher: 10 kg./mm.^{2}. Stress peaks also were found at the beginning and end of the weld. Altogether these experiments show that welding stresses above the yield point are possible in plates of large section in the unconstrained state.

Further tests were performed to determine the stresses in half-constrained plates using the method of C. H Jennings (Am. Welding Soc. Journal, **10,** 27–30 (1931)). The center portion of a plate 25 mm. thick was planed to 12 mm. thick and so divided in the middle that a crosspiece not cut away and 90 mm. broad by 25 mm. thick remained at the margins and was considered as restraint. The crosspiece was separated by milled grooves over a total length of 1190 mm. from the plate to be welded so that only the outer ends of the plate were constrained over a length of 200 mm. The welding and measurements were performed in the same way as described above. Using the average boundary stress (compression), which was 6.6 kg./mm.^{2} at the beginning of the weld (the point where the weld was started) and 9.1 kg./mm.^{2} at the end of the weld, Mies computed an average tensile stress in the longitudinal direction of 7.3 kg./mm.^{2}; actual measurement gave a stress of 6.15 kg./mm.^{2}. This emphasizes the fact that the stress distribution in the direction perpendicular to the welded seam is completely non-uniform (non-symmetrical) and that the greatest tensile load occurs in the seam itself. The average stress in the seam was 12.1 kg./mm.^{2} and was therefore somewhat higher than in the unrestrained plates (the plates that were free to move). In the direction of the seam itself the greatest tensile load was 17.7 and the average stress 16.2 kg./mm.^{2}, a stress which is much lower than that obtained by welding unrestrained plates. The tensile stress in the seam itself naturally produces compression stresses in the plate near the seam which decrease as the distance from the seam increases. On the basis of these values Mies is led to a more favorable estimation of the arc welded restrained plates. The same tests applied to gas welding were a failure because the boundaries buckled outward on cooling after welding, whence Mies calculated a boundary stress of 20.5 kg./mm.^{2} on the basis of the bending. From this we may conclude that a much higher stress exists perpendicular to the direction of the welding, which, to be sure, cannot be calculated. The reason that failures in the form of stress cracks occur more frequently in practice in arc welded, than in gas welded, restrained plates lies in the peculiarities of the two processes. While the whole cross section of the seam is filled up in one run in gas welding and the greatest stresses occur only after the welding is finished; in arc welding, on the other hand, the plate thickness is built up in several runs. The rapid conduction of heat away from the weld after each run gives rise to high stresses which naturally have greatest effect on the smallest cross section, that is, the whole deformation occurs in the joint, which in unfavorable conditions is not in the run. If the welding process is adjusted in the light of these facts, failures are certain to be avoided.

Hitherto there has been agreement as to the absolute magnitude of welding stresses only in a few of the known methods that have been used. In agreement with other investigations the maximum value determined by the extensometer method as well as by the drill-hole method was only just above the yield point of the material welded.

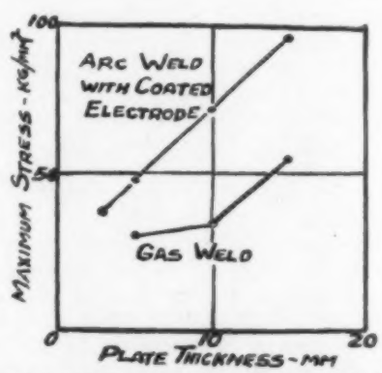


Fig. 2—Maximum Stress in the Longitudinal Direction of Arc and Gas Welds as a Function of Plate Thickness (According to Bollenrath)

In contrast with this, F. Bollenrath (*Abhandlung Aerodynamische Inst. Techn. Hochsch. Aachen,* **1934,** No. 14; see also A. Mullenhoff, *Elektroschweissung,* **6,** 103–108 (1935); E. Siebel and M. Pfender, *Arch. Eisenhuttenwes.*, **7,** 407–415 (1933–1934)) using the boring method of J. Mathar (*Arch. Eisenhuttenwes.*, **6,** 277–281 (1932–1933); *Werkstoffausschuss* 202) came to fundamentally different conclusions. Although generally in the above-mentioned methods it is assumed that the change in thickness of the plate, being only a slight source of error, may be neglected, Bollenrath measured deformations considering plate thickness as well. This method is fundamentally more accurate. Besides, in many methods the gage length, which is the basis of the measurement of elongation, must be fairly large in order to determine the elastic deformation with sufficient accuracy. This is a disadvantage because the stress is not measured at a single point but as an average value over a definite length. The method Bollenrath adopted showed that the maximum stress in the weld is largely dependent on plate thickness. Figure 2 shows the maximum stress in the seam direction using gas welding and also arc welding with coated electrodes. Bollenrath also found that the stresses were higher the narrower the zone of heating during welding; that is, in other words, assuming uniform strength in the weld, the stresses

will be highest with bare electrodes. As the strength of the weld deposit increases, the welding stresses also increase. On the other hand, transverse stresses are extraordinarily small. Bollenrath states that the stresses are not materially decreased by peening; still he found a definite equalization of the stresses that had hitherto fluctuated exceedingly. This practice of forging is of advantage therefore only in so far as it improves the quality of the deposited metal. Tests on stress elimination showed that external loading of the welded seam caused a decrease of stresses but existing stress peaks remained although their absolute magnitudes were lowered. The degree of stress elimination by external loading is greater in gas welding than in arc. Stress elimination was not obtained either in gas or in arc welds by applying elastic loads in the form of impulses. In agreement with O. Mies, Bollenrath also found that in plug welding lower shrinkage stresses were produced in the constrained condition than in the unconstrained. Bollenrath further found from his tests that it is advantageous to have the same technological properties in the deposit as in the parent metal as far as possible, since then the least shrinkage stresses are produced in the joint.

Using Bollenrath's results, H. Buchholz (*Autogene Metallbearbeitung*, **28,** 82–89 (1935)) dealt further with the question of stresses in welded joints. Using Bollenrath's conclusions as a basis, he assumes that elongation at yield point, elongation in the tension-impact test and notch impact value are of decisive importance in eliminating shrinkage stresses and estimating the safety of structures. G. Bierett (*Autog. Metallbearb.*, **28,** 122–123 (1935)) argues against this, stating that experiments have shown that stress elimination by external loading occurs by means of plastic deformation. Bierett also rejects the relation between notch impact value and stress elimination since, up to the present, there have been no tests whatever to substantiate any influence in the direction and that Bollenrath's results permit no conclusion of that sort to be drawn. Bierett also disagrees with the view that, in contrast to the shrinkage stresses computed by Bollenrath, constructional stresses are less dangerous, since, up to the present, proof to the contrary has been lacking and constructional stresses exert loads rather to be dealt with than the shrinkage stresses.

A comparison of the stress determined by Bollenrath with those previously determined shows that Bollenrath's stresses are considerably higher and often amount to several times the stresses previously reported. Such high stresses cannot be explained by consideration of plate thickness alone. As basis for his work he used earlier tests on stresses in perforated rods. Even if this basis is not brought into question, the doubt remains as to how far these earlier tests may be applied to welds. In support of this doubt the following statement may be made. Bollenrath shows, for example, that welding stresses rise with decreasing width of heating zone, which means, assuming uniform strength in the weld, that welding stresses will be smaller with coated than with bare electrodes. However, it is well known in practice that cracks occur more often with coated than with bare electrodes. Bollenrath's statement that peening decreases the stresses only slightly is not in agreement with results of other tests. It is general knowledge moreover that cracks rarely occur in long seams in plate that is not too thick, whereas if the seam is repaired in spots, especially in the way Bollenrath adopted, cracks frequently occur. It is remarkable, too, that cracks very seldom originate from the high longitudinal stresses that Bollenrath found, but generally originate through transverse stresses, which according to Bollenrath are smaller. These facts considerably reduce the value of the absolute values of stress because the safety of a structure is obviously independent of them.

L. Hunsicker (*Autog. Metallbearb.*, **27,** 361–364 (1934)) solved the problem of avoiding warpage by welding on both sides with the same speed so that warping on one side cannot occur. This procedure is adaptable for fillet as well as butt welds. Hunsicker shows how to carry out the procedure on a number of dynamically loaded structures.

H. Dustin (*Arcos*, **12,** 1215–1221 (1935)) reported some notable fatigue tests on models. His tests were made on models to the scale of 1:2.5 of Vierendeel girders in the bridges at Schooten. These girders were tested in a horizontal Amsler Pulsator. In testing under static load it was found that the actual stresses were much higher than the computed maximum value. Theoretically, the boundary values in the vibration test of the roadway should vary between 2.4 kg./mm.^{2} compression and 7.5 kg./mm.^{2} tension. To determine the factor of safety, fatigue tests were first made with a tensile load of 12 kg./mm.^{2} for 2 million vibrations. No fracture occurred in the girder. Fracture occurred however at loads of 14 or 16 kg./mm.^{2}; after about 1.6 million cycles at a load of 16 kg./mm.^{2}. It is therefore believed that the fatigue limit of the girder lies slightly below this last-mentioned load. The factor of safety is therefore more than $1^1/_2$ from the ratio of calculated to actual fatigue strength.

The next three paragraphs abstract papers published in AMERICAN WELDING SOCIETY JOURNAL:

J. H. Zimmerman, AM. WELDING SOC. JOURNAL 13 (9), 13–15 (1934).

A. J. Moses, AM. WELDING SOC. JOURNAL, **14** (4), 5–19 (1935).

R. K. Hopkins, AM. WELDING SOC. JOURNAL, 14 (3), 4–7 (1935).

4. Service Results

H. Frankenbusch (*Autog. Metallbearb.*, **28,** 97–130 (1935)) reports the use of gas welding in fabricating galvanizing kettles. This problem involves not only the design of the kettle but the attack of zinc on the materials of the weld. So-called "Corner" welding gave very good results on these kettles. The formation of iron-zinc compound frequently occurs as a corrosion phenomenon in the seams. As a result, extraordinarily high stresses occur when a cold bath of zinc is heated; often the kettle is burst. Frankenbusch strongly recommends the use of butt joints in the longitudinal and, if necessary, in the transverse sides of the kettle. "Corner" welding on the bottom leads to no trouble since the layer of iron-zinc compound on the bottom protects against further attack. All welded seams must be dense and free from porosity since otherwise corrosion is more extensive in the joints than in the parent plate itself. It is best to use a low carbon rod for welding to obtain protection against attack.

The concluding three paragraphs summarize American papers:

A. F. Davis, AM. WELDING SOC. JOURNAL, **13** (9), 2 (1934).

A. E. Gibson, *Weld. Engr.*, **20** (3), 15–17 (1935).

E. G. Doan and A. M. Thorne, AM. WELDING SOC. JOURNAL, **14** (4), 22–24 (1935).

Saw Welding

By E. E. OLSON†

Highly Specialized Operation Worthy of Note

A HIGHLY important consideration in the welding of saws is the fact that good quality steel saws, whether they are band saws or circular saws, have been manufactured under an intricate process of heat-treatment and working. Such a saw, when purchased new, has a tensile strength of about 172,000 lb. per sq. in. This is, obviously, much different from common steel and is the first reason why the material is one for careful consideration. Primarily, the effect of the welding heat on such material is the repairman's first interest. Procedure controls for saw welding have been developed as the result of much experience, and it is essential that they be followed closely.

The application is not new. In fact, throughout the lumber industry, it is general practice to repair saws by this method. In practically every lumber mill saw maintenance shop carefully controlled procedures have been worked out and are followed with painstaking care. Under no circumstances is a welding operator permitted to work on a saw until he is thoroughly familiar with the routine for each different type of repair. In lumber mills generally the head filer is usually charged with the entire responsibility for the saw welding. No one else is permitted to do the work because of the rigid safety requirements necessitated by the nature of the part. The welding of saw steel is an art in itself and is one that demands a great deal of study, constant practice and close supervision. The job is done today and done well, and because procedures vary somewhat in different parts of the country, practices now current are of interest.

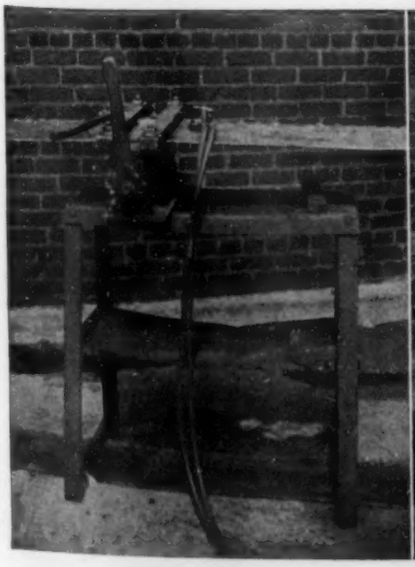
† The Linde Air Products Company, Seattle.

Metal Must Not Be Overheated

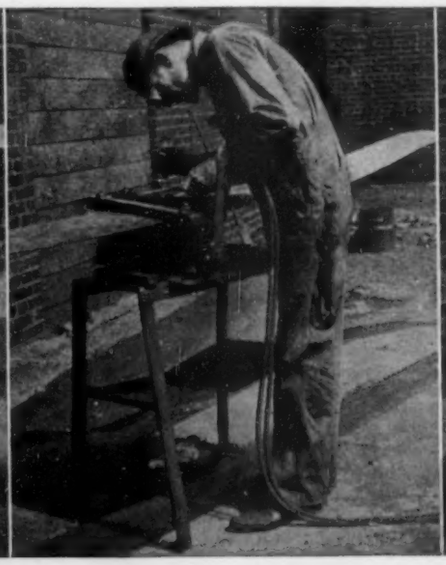
As in the case with any metal that has been heat-treated, special care is necessary when welding. This is essential because of various factors more or less generally known. Primarily, overheating of metal that has been developed to a high strength through both heat-treatment and working should be avoided. This holds true for work on saws as on other similar materials, such as spring steel. Do not overheat the metal. This can be accomplished by welding a small spot, not exceeding 1 in. at a time, and immediately forging the weld as each weld section is completed. Overheating of any considerable area is thus eliminated. Fine metal grain structure similar to that of the original saw steel will result from this method of treatment. Overheating during welding or the omission of forging may cause brittleness and a considerable reduction in tensile strength.

The heating or the welding of a small spot at a time is essential for good results. On the other hand, mere repeated heating and cooling of the weld may cause hard spots which are likely to crack after the first run of the saw. In order to take care of this possible effect, the weld and the welded area should be heated to a dull red and allowed to cool slowly immediately after the entire weld is completed. The heated section is then uniform in hardness; but the total heating leaves the material too soft. A second heating after the section has been cleaned with emery, carried out slowly and applied until the material is of a straw or blue color is then necessary. The section is then allowed to cool off.

The manufacturer of the saw is in the best position to recommend the best welding rod to use on his products.

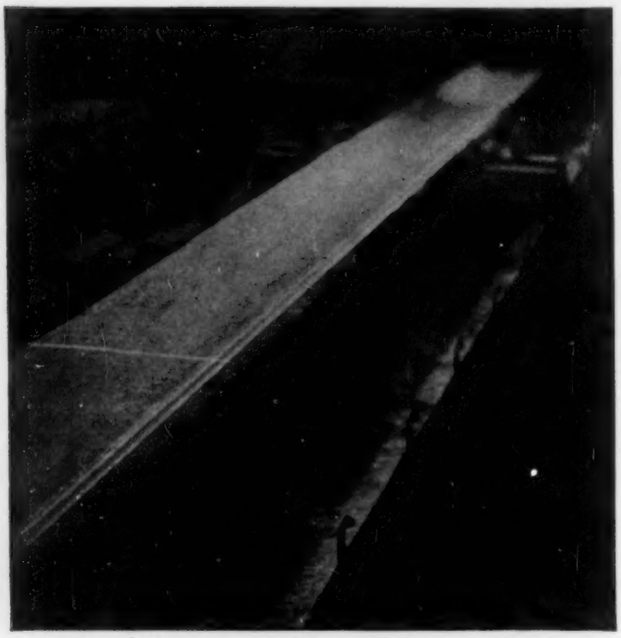


A Jig with a Movable Anvil Assists the Saw Welding Operations



Short Welds Are Essential to Prevent Overheating

Immediately Following Each Short Weld, the Metal Is Forged to Relieve the Stress and to Refine the Grain of the Metal



Saw Steel Belting for Composition Board Manufacture Is Made Endless by Welding

Special Considerations

It is recommended that the backhand method of welding be used. For this, the flame is pointed toward the starting point of the weld; in other words, back over the completed weld.

There are many special considerations in connection with the repairing of different types of saws and different types of fractures.

When working on band saw cracks, always start from the inside end of the crack and weld out toward the edge. On head saws, because of blade thickness, the crack should first be opened up with a hard blunt chisel. Thus better penetration without overheating is obtained.

Butt type welds require special anvil jigs to hold the blade in position and to permit the operator to forge the weld at the correct time. Current practice does not require beveling of the edges. The ends are lined up about $^1/_{32}$ in. apart. The weld is started in the center of the blade, carried 2 in. toward one edge, and then restarted at the center and carried the same distance toward the other edge. This welding short distances on alternate sides from the center continues until the entire weld is completed across the saw.

To replace a tooth, an entire tooth should be cut from a scrapped saw. The edges are beveled, one end of the tooth tack-welded to the saw, and starting from the opposite end of the crack the weld is carried through to the tack-weld. As usual, the tack-weld must be melted out and rewelded.

Broken circular or round saw teeth require the same method as band saw teeth. Cracked rims are handled differently. Because of greater thickness, and to eliminate warping, the weld is made from both sides working from the inside of the crack toward the rim. Any buckling of the metal is hammered out. As the welding flame heats the metal the saw buckles upward. This is taken care of by welding about $^1/_2$ in. halfway through the metal. The saw is quickly turned over and the other half welded from the other side. Again rapidly turning over the saw the buckle is hammered out while the steel cools. The process is repeated until the crack is completely welded.

A broken eye requires special equipment and is usually not attempted unless absolutely necessary. Work of this nature should be turned over to someone specially equipped to do it.

An Interesting Jig

A southern company does a great deal of this work and saw welding is quite common for them. Of particular interest in their procedure is the special jig developed for handling the work. This holding fixture has been devised particularly for making butt type welds on band saws. It consists essentially of two clamps which hold the ends of the saw in exact position for welding. An anvil which fits directly underneath the part to be welded and which can be raised or lowered at will without removing the saw from the clamp is also provided. In this way the alternate welding and peening or forging takes place as rapidly as possible and with a minimum of effort and lost time.

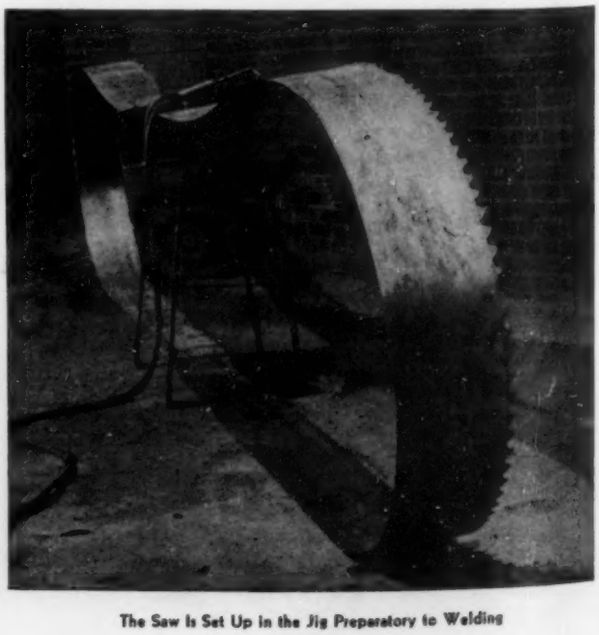
Their procedure is to clamp the saw in the jig with the anvil lowered so there is a space between the bottom of the saw and the clamp where the weld is to be made. The weld is started at the inside of the crack or check. About 2 in. is welded at a time toward the edge of the saw. The anvil is then quickly raised and the welded section hammered lightly to stretch it while it cools. This procedure is continued until the crack is completely welded.

When they weld a saw that is completely broken in two, or where a splice is being made, the saw is clamped quite securely in the fixture and the welding started in the center. Again 2 in. of welding is completed at a time immediately followed by forging. The anvil in the jig is of course raised up against the bottom side of the saw the instant the welding is stopped. Following completion of welding, the entire welded section is reheated and normalized and then tempered again.

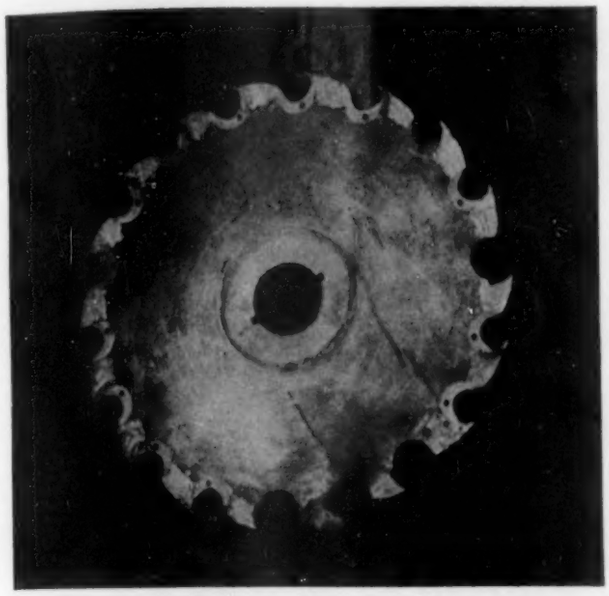
For Steel Belting

In the Northwest, a company that manufactures a special composition board, which is made out of shredded wood and a mineral mixture, finds the saw welding procedure excellent for the welding of steel belting used in their board-making machines.

Each belt is about 240 ft. in length, 24 in. wide and



The Saw Is Set Up in the Jig Preparatory to Welding



Worn Spots on Removable Tooth Round Saw Are Rebuilt by Bronze-Welding to Eliminate Overheating

of approximately 20 gage Swedish band saw steel. Before the application of welding to this job, mechanical joints were used to join the ends thus making the belt endless. These mechanical joints seldom lasted over four months.

With the adoption of the regular saw welding technique splendid results followed.

An anvil similar to those employed for band saw welding, having a movable anvil and clamp, is used for this work. The same procedure for welding is also carried out. Upon completion of the weld, the slight weld reinforcement given during welding is filed down to original belt thickness.

In this particular plant five machines are used for making the various thicknesses of composition board and two belts are used on each machine. The machines are operated with a 20,000-lb. tension applied on each of the belts. The belts are accurately spaced for the correct board thickness and run through a 90-ft. blast heated furnace. The materials for making this special board are fed in at one end of the machine, packed between rolls and slowly pulled through the furnace on the steel belting. A solid slab of dried and hardened composition board emerges at the other end of the furnace.

This is certainly heavy punishment to give a weld, but it is interesting to note that the welded bands last for a year or more as against three to four months maximum for the original mechanical joints.

Bronze-Welded Saw Teeth

A very interesting application was reported not long ago from a Northwestern lumber company, which used circular saws of a type having removable teeth. The teeth would wear out just behind where the tooth was inserted on the main blade, and for some time it had been customary for them to build up the teeth in the worn spots with steel welding rod.

This procedure seemed to set up strains around the rims of the circular saw and, as it was not a question of tensile strength in this case, an oxyacetylene service operator suggested that bronze welding rod be tried out for the rebuilding operation.

A six months' trial of this showed the application to be sound, as it eliminated many of the problems encountered in the former rebuilding operation.

It is reported that the operation is very simple because the bronze rod will "wash" on in quite a thin layer. Another thing is that a great deal less heat is necessary which tends to eliminate warping.

About $1^1/_2$ lb. of bronze rod, an hour's welding time, and 6 hr. of filing, grinding and putting in teeth are required for this work. The lumber company management reports that they consider a cost of under $6.00 for this work very good and the operation is to be continued as standard.

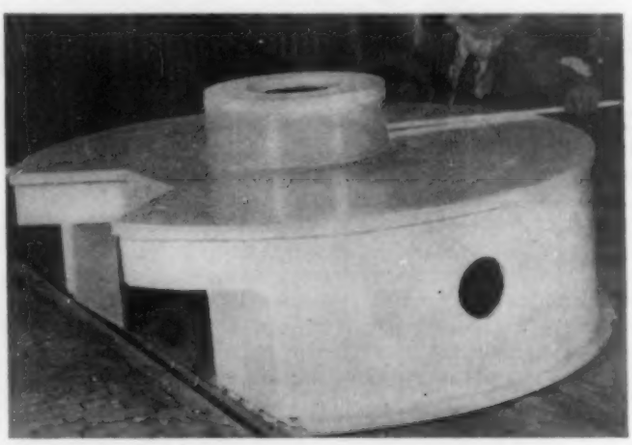
As mentioned at the beginning of this article, repairing saws by oxyacetylene welding is a highly specialized procedure and not one to be gone into by the inexperienced operator or welding shop. Highly specialized technique and equipment are required. A thorough understanding of the nature of the material being worked on, as well as a knowledge of how to handle the effects of welding on this material, is essential. The work, however, when properly done, solves a widespread maintenance problem that is faced by any company using this type of saw and it therefore justifies careful study.

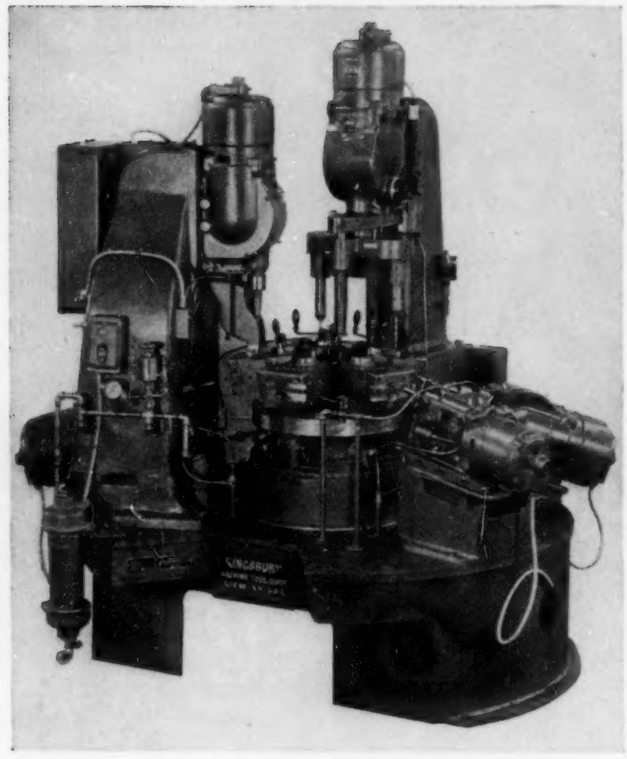
Light-Weight Rigid Welded Base on Kingsbury Drilling Machine

By G. DONALD SPACKMAN†

KINGSBURY Machine Tool Corporation of Keene, New Hampshire, recently built an automatic indexing drilling machine for handling various drilling operations on a rear main bearing cap. In general, the machine follows closely the design and construction of the well-known Kingsbury automatic drilling and tapping machines which have been responsible for

† President, Lukenweld, Inc., Division of Lukens Steel Co.





many notable improvements in production methods in the lighter ranges of work.

The machine is equipped with a welded steel main base fabricated by our Company, using a special analysis of welding quality steel and employing covered electrodes under insurance welding control. The finished welded structure was thoroughly furnace-stress-relieved before shipment.

The welded base is 67 in. in diameter and 36 in. in over-all height, including the 9 in. center pedestal. Eighteen pieces of flame-cut and formed steel plate were used. In the internal stiffeners, $^1/_2$-in. plates were used, $^3/_4$-in. plate in the main shell and $^7/_8$-in. plates in the top and bottom flanges.

In order to preserve drill alignments and eliminate the possibility of chatter in the machine, it was necessary that the design and construction of the base provide for a substantial and rigid structure. However, it was essential that weight be kept at the minimum. These requirements were met in the welded unit which weighed only 2420 lb. in the rough, and about 2100 lb. after machining. For equivalent rigidity in cast iron, it is estimated the base weight would have been about 3600 lb., an increase in weight of about 71% over the welded base. In cast steel of equivalent rigidity, it is estimated the base weight would have been about 2800 lb., an increase in weight of about 33% over the welded base, due to the fact that in a unit of this size, difficulty would be encountered in the foundry in attempting to cast the $^1/_2$-in. and $^3/_4$-in. sections employed in the welded structure.

Maintenance Welding in Railroad Works*

By FRANK A. LONGO†

WE WHO have grown up with welding on the railroad, can well appreciate the safety of equipment used now as compared with the equipment used in 1914, when welding was first started at our Los Angeles shops. In those days, we had numerous accidents, such as, regulators catching fire, some blowing off, equipment back-firing and burning operator, and acetylene generators blowing up. We have had no accidents due to equipment in the last several years.

The responsibility resting upon us today is greater than ever before, both from the viewpoint of safety and economy; and will continue to grow greater as time passes, because we are doing more welding today than ever before.

Arc and gas welding and cutting are used in roundhouses, car shops, boiler, blacksmith and machine shops; also, for sheet metal workers and pipe fitters for new and repair work in various branches of the metal trades. We find the oxyacetylene and arc process for welding and cutting indispensable for quick, efficient and economical results.

The success of a welding job depends a great deal on how it is prepared, and for this reason the welder should see that the work to be done is properly beveled and edges thoroughly cleaned from dirt, scale and grease. Work should be secured in position with suitable strut bolts, clamps or wedges, with the proper opening to enable the welder to perform the welding all the way through the plate or job, and make the weld solid.

Gentlemen, if you will follow me, we will go through all the processes involved as the locomotive and tender go through the shops for heavy repairs. We will especially observe the important part played by cutting and welding in the overhauling of a large locomotive

When an engine is shopped, tender is disconnected from locomotive and sent to tank shop. Locomotive is placed on strippers pit where a gang of strippers remove all pipes, jacket, lagging, cab fixtures and running boards. Binders and brake rigging are loosened so they can be easily dropped when engine is placed in back shop.

After engine is placed over pit in back shop, the heavy stripping is done such as dropping binders, brake beams, safety hangers, cab removed, front end, superheater units, throttle box and stand, air pumps, feed water pump, injector, air reservoirs, cylinder heads, pistons, crossheads, main and side rods and all brackets on boiler. We have well trained oxyacetylene cutters in stripping gang, who burn all bolts and nuts to facilitate the removal of parts mentioned. Engine is lifted and wheels removed. Engine and trailer trucks, booster engine, spring rigging, shoes, wedges and driving boxes are then removed and taken to their respective departments.

During time strippers are on engine we have three cutters who cut out bolts and rivets in ash pan for removal, then burn out fire-box sheets, radials and stay bolts. We usually have fire-box burned out before strippers are done. Flexible bolts and radial bolts are burned off next to both sheets for reclaiming. Boiler is then lifted from frame and taken to boiler shop.

* Presented at the 233rd Meeting of the Pacific Railway Club, Jan. 9, 1936.
† Supervisor of Welding, Southern Pacific Company, General Shops, L. A.

Frames, frame braces and cylinders are cleaned and examined for cracked or broken parts.

Locomotive Cylinders

The repairing of cracked or broken locomotive cylinders has always presented quite a problem to locomotive repair shops, but the development of the various processes of fusion welding has tended greatly toward the simplification of this problem. The oxyacetylene torch is used to fuse a bronze filler rod into the parent metal of the cylinder. When this process is properly handled, an ideal cylinder repair will be effected. The building of the furnace is one of the most important operations of the process, and often too little attention is paid to it. It is best to enclose the entire cylinder half within a furnace built of fire-brick. However, when the weld is only a small one in the bottom of the cylinder proper, only the cylinder and valve chambers need be enclosed. Steam pipe to cylinder must be disconnected at header to allow cylinder to move freely during expansion and contraction.

Cylinder should be preheated with charcoal for five or six hours. This preheating is accomplished by placing a grate of small mesh wire netting half way up from the bottom of the cylinder and valve chambers, placing charcoal on this netting, also on floor of furnace. This preheating is necessary for the following reasons:

1. To prevent the weld metal and heated metal close to the weld from being hardened due to the chilling action of adjacent cold or nearly cold metal.
2. To prevent the further breaking of the casting due to the heat of the weld or the breaking of the weld due to unequal contraction during cooling.
3. To save welding gases and time.
4. To make welding easier.

Charcoal must be added to the furnace during the welding operation to keep cylinder hot and at an even temperature. When welding job is finished, cylinder is again fired up and furnace sealed to allow cylinder to cool down slowly to relieve all stresses due to contraction. This should take from 48 to 72 hours.

The straight welding torch was first developed in our shops in Los Angeles in 1925 as we use welding tips from 15 inches to 48 inches long for this work. The development of this straight torch came about as the result of welders getting severe cases of bronze poisoning on account of having to work so close to bronze in these heavily heated cylinders. Now they can stand back two or three feet.

Another operation consists of building up worn sides of guides. This is one of our shop practices to maintain the dimension of our guides to standard. When removed from the engine, all foreign matter is removed so they will have a clean surface. We lay mild steel rods $^{3}/_{4}$ inch apart, the length of the weld, and the thickness to be built up on the sides. As this weld is only in compression, it is permissible to fill in with rods to cut down welding time. $^{5}/_{32}$-inch diameter electrodes are used to weld in first bead to get good fusion at bottom of mild steel rods, then $^{1}/_{4}$-inch and $^{5}/_{16}$-inch diameter electrodes are used to fill in, thus making a solid weld. Guides are then straightened and milled to standard size.

Locomotive Frames

Of the various methods of fusion welding, the electric arc process is, in the large majority of cases, the most economical for use either in repairing broken locomotive frames, or introduction of a new section to replace an old, crystallized section. The process is not difficult, but there are certain precautions that must be taken if positive success is to be assured. All too often, in order to save time, proper procedure is not followed, and the weld is a failure. This, as is self-evident, is not a failure of the process, but is chargeable to careless supervision.

When engine comes in with broken frame an effort is made to determine the cause of the break, as there are several causes of frame failures, a few are: crystallized frame or fatigue limit, broken and loose binders, frame braces loose and working, driving boxes and rods pounding.

Before cutting frame for welding, it is always necessary to place jacks beneath the frame, to prevent any strain from interfering with the proper alignment, and the securing of expansion. After frame is lined up, the frame must be trammed parallel across the break, also crisscross on a large frame. Tram marks must be far enough on either side of the weld, or outside of the annealing range. The tram marks should be made with a center punch.

The break is then cut out with a cutting torch from both sides to center making a double vee; the angle of both openings should be 60 degrees. If the frame near the break contains flaws, all defective metal must be cut out irrespective of the size of the section affected.

If a short section is applied it should be made of a good grade of double refined grained iron, as we have found from experience that a steel section is too brittle, and not ductile enough to stand the strains and stresses in a large locomotive frame. We have had four steel sections give us trouble before we changed to iron and this trouble was eliminated, as this grade of iron is tough and ductile.

After frame is cut for welding about 8 inches each side of break must be heated to relieve or reduce any crystallization, also to remove all grease or oil which might enter into metal deposited. After cooling, the frame is chipped smooth with a chisel. A sealing tool having a knurled striking surface must never be used, as it has a tendency to beat a large part of the scale into the surface of the steel. This interferes with the welding.

The frame is then expanded at break to allow for contraction that takes place during cooling when the weld has been completed, also, to allow for contraction that takes place during annealing that is given weld and frame. The amount of expansion varies from $^{1}/_{16}$ to $^{3}/_{8}$ inch depending on the size of the frame. Tools used to expand frame are jacks, wedges and a natural gas torch, the latter to heat opposing frame member when necessary to expand frame in this manner.

Before welding is started, the frame must be checked to see that the expanding action has not forced the frame out of line.

The welder will start at the bottom of the gap between the apex of the vees cut into the frame, and weld to the top. The first bead must extend completely through the vee. A chisel must never be used to remove scale after weld is started. Only the regular welder's tools must be used to remove scale. These tools are: a hand scaling hammer, wire brush, a small air gun and caulking tool about $^{3}/_{8}$ inch thick. The latter is used to bob and expand the weld metal to relieve contraction stresses.

We always use two welders for frame welding, one on each side of vee; this is in order to prevent warping of the frame and to cut down welding time on job. The weld is composed of well-formed vertical beads, each of which is $^{1}/_{8}$ inch thick and $^{5}/_{8}$ inch wide. The scale from each layer of the deposited metal must be cleaned and metal bobbed lightly.

We have found the $^{3}/_{16}$-inch heavy coated rod best for frame welding. One-fourth inch heavy coated is used on broken pedestal jaw lugs.

After welding is completed frame is stress-relieved. This heat treatment consists in bringing the weld and adjacent metal up to a medium red heat, holding heat long enough to soak through weld, and allowing it to cool slowly.

A piece of plate used as a furnace support is hung on the frame, and upon this plate the brick furnace is built to anneal frame.

The welding of a frame must be carried through from start to finish in one operation. Cooling at any time during the process would result in heavy stresses being set up.

Fire-Boxes

By the use of treated water, and the continual renewal of patches and sections of fire-boxes and front flue sheets in the back shop, the program of new fire-boxes is a thing of the past; and justly so, for it is an expensive proposition to strip and remove boiler from frame for this work.

A few years ago, it was "How many fire-boxes can you put in?" Now it is, "How many fire-boxes can you save?"

I recall the old slow method of applying patches in fire-boxes with patch bolts and sewing up cracks with plugs. Hot workers were continually working on leaky stays, flues, rivets, plugs and patch bolts.

Boilermakers in those days were in demand as we had several all along the line keeping fire-boxes tight.

I have before me a chart showing number of fire-boxes applied during last 23 years. It is very interesting to note in the last few years reduction of number of fire-boxes applied.

In the 12-year period from 1913 to 1924, a total of 2127 fire-boxes were applied on Pacific System. In the 11-year period from 1925 to 1935, this dropped down to 977 fire-boxes. At Los Angeles during the year 1920, we put in 104 fire-boxes. In 1925 this dropped down to 36, and last year, 1935, *only one* fire-box was applied.

With our old method acetylene welding, patches and cracks in side sheets were common cause of failures on the road. Men had to be sent from our shop to reweld these cracks at outside points.

Joining sheets in the locomotive fire-box by the electric arc process, using a heavy coated welding rod has effected considerable economy, both in fire-box construction and maintenance cost; as welds equal to or better than the plate itself in tensile strength, ductility and ability to withstand repeated stresses are obtained.

On rare occasions, we do have to put in a new fire-box. These combustion chamber fire-boxes consist of crown, door, back flue, two side, throat and bottom combustion chamber sheets. Sheets are held in place with straps and strong backs.

The only riveted seams we have in this type of box is the door and flue sheets, which I hope our people will see fit to let us weld some day. When we apply patches to door sheet or bottom of back flue sheet without removing all lower flues, we weld them in.

The type of weld used in new fire-boxes is the single vee butt weld, and as the welders have access to both sides of the sheet, the seams must be welded from both sides. After box has been welded completely from fire side, a diamond point chisel is then taken, and a vee-shaped groove is cut in the back of the weld of sufficient depth to remove all flaws. This groove is then welded, and a weld of maximum strength is secured. Caulking edges of door sheet, flue sheet and four mud ring corners are sealed with electric welding.

The life of a new fire-box is extended by the application of reinforcing bars, properly fitted to flanged radius welded vertically between each row of stay-bolts. These are butted up against crown sheet and extend along knuckle down to midway, between first and second row of stay-bolts. Bars on throat sheet wings are placed horizontally 4 inches apart, and $^1/_2$-in. thick back mud ring corner patches are applied instead of $^3/_8$-inch, as all of these give trouble first, due to cracking, and are the weak spots of a fire-box. The application of these $^5/_8$-inch round iron bars, length to suit, have extended the life of these parts from 50 to 100%.

In the welding of patches in fire-boxes, front flue sheet and smoke box, the edges of both the old and new sheets must be clean and beveled at a 30 degree angle, or 60 degree opening for both. The new sheet should be bolted so that a gap of $^1/_{16}$ inch is left. The seam is tack-welded about every 15 inches, this so the patch cannot get out of line, after which the straps are removed. Patches are applied to any part of the fire-box.

The first bead, or pressure bead, is made with $^1/_8$-inch diameter welding rod to insure penetration as the weld in the water side must be clean and flush with the sheets, with no gaps or mud catchers.

The first bead is laid directly in center of the seam. No attempt should be made to fill the gap with the first bead. After first bead is applied $^5/_{32}$-inch and $^3/_{16}$-inch diameter electrodes should be used and each layer of weld metal must be thoroughly cleaned of all scale.

In repair shop, applying tops of door sheet, back flue sheet and throat sheet wings, these bars are applied before patches are set in place.

In applying patches to front flue sheet, enough flues must be removed to enable welder to reinforce weld from water side. Usually the whole knuckle below the unit header is removed and three patches applied.

If back flue sheet is renewed a $^3/_4$-inch front flue sheet is applied instead of patches, that is, front flue sheet is cut horizontally above top row of flues to save removal of unit header. This top section is well braced. Deterioration and cracking is not so rapid. Half-inch gusset plates are welded to knuckle of front flue sheet in smoke-box side. The life of cracked front flue sheets has been extended by the welding of the crack and the application of these gussets.

Front flue sheets $^3/_4$ inch thick have been applied to three locomotives, which are still in service. One applied to Engine 4311 Dec. 28, 1925 is 10 years old. One $^3/_4$ front flue sheet applied to Engine 4302 Dec. 1926, removed Jan. 11, 1934, gave 8 years of hard service. Three-fourth-inch thick front flue sheet applied to Engine 4320 Jan. 1928 is still in service after 8 years. Three-fourth-inch thick front flue sheet applied to Engine 4354 April 18, 1932 is still in service.

The welding of superheater flues to back flue sheet is one of our first applications of welding. In 1916 average cost to weld in set of 36 superheater flues with oxy-acetylene method was $66.00 as welder finished only one flue per hour. We now electric weld this same set of flues in $4^1/_2$ hours at a cost of $6.00.

It was Mr. O. B. Schoenky, now Superintendent of Motive Power, of the Southern Pacific Company, and one of the Pioneers of welding, who first saw the possibilities of electric welding, replacing the oxyacetylene method for our work; as in April 1917 he wrote the following to Mr. Pat Sheedy: "Now that the demonstration has been completed on the autogenous welding, we should adopt the apparatus that will give us the best results for the least money, which other roads have already proved is the electric welding outfit." The result was that in the following year, 1918, we purchased our first electric welding machine.

At the present time, we have 18 electric welding machines with two shifts of welders, and 3 machines in roundhouse to take care of running repair work.

The holes in back flue sheet for superheater flues are countersunk at a 45-degree angle half way through the sheet. The flue is cut so that it will lack about $^1/_{16}$ inch from coming through the sheet in the fire-box. The flue is then given a light rolling to set it to sheet and then prossered as close to the sheet as possible. Flue is belled out or laid over in the countersink, after which the flue end is welded with a good substantial bead, fusing well into the end of the flue to make a strong welded joint. There is no projection of the weld on the fire-box side as this weld is flush with sheet, and will run the life of the flues without giving a bit of trouble.

We do not weld our small flues until the life is about gone from flue beads. They are expanded, beaded, rags cut, cleaned and sandblasted for welding. A small bead is then welded around flue bead and their life extended about 14 months. In combustion chamber fireboxes it is much longer.

Oxyacetylene welding is used in the repair of pit holes in flues and in the welding in of pieces of superheater flues. In the welding of superheater flues, the bottom of the vee is fused together before filler rod is added. This makes a solid weld of maximum strength and the weld is always flush with the inside flue walls.

After ash pan is bolted in place, all seams are electric welded to insure against cold air striking fire-box sheets and falling of brick work.

Wheel Diameters

Another very important job is the maintaining of fixed diameters and true circles on locomotive driver and trailer wheel centers. The method in general use for changing and resetting the tires of locomotive wheels, is to heat the tire until it expands sufficiently to allow slipping it off the wheel center, and then replacing it with the same or new tire, which is expanded by heating, until it readily fits the wheel center. The tire is then allowed to cool and in cooling, shrinks upon the wheel center, assuring a tight fit.

A continuation of this process reduced the diameter of the wheel center and has an injurious effect upon the roundness of the rim section until it becomes necessary to build up the wheel center.

The reducing and deforming effect of this method of changing tires is traced to several causes. The principal cause is the contraction stress inherent in all irregular shaped castings. Because wheel centers are cast steel, and the light spoke and rim section is opposed by the heavy hub, crank pin, boss and counterbalance section, the contraction strain on the lighter section of the wheel is excessive, deforming the wheel to some extent.

In addition to this strain, there is the contraction strain imposed by the shrinking of the tire upon the wheel center. This strain tends to increase the concavity of the wheel on the inside, thus reducing the diameter. Also, irregularities in the track, subject the heavily loaded wheel centers to considerable pounding, which decreased their diameters.

As engine goes through shop, we weld up all the wheel centers that are undersize. Following is our standard practice of maintaining fixed diameters and true circles on locomotive wheels:

Before wheels are taken to welders, wheel center rims are thoroughly sand blasted to remove scale and rust on surface to be welded, as a clean surface is necessary for better and faster welding.

Wheels are then put on a set of rollers equipped with a reversible motor and four rollers, the same as used for setting eccentric crank arms. Air hose attached to motor has a cut-out cock in line, placed in reach of welder for turning wheel to suit position of welder, who welds about 18 inches and then turns wheel. The welder can sit on a stool about 36 inches high, in a comfortable position, and by avoiding muscular strain, can better concentrate on the work.

The cable to the electrode holder should be drawn over the welder's lap from the left side with just enough slack to allow free motion of the electrode holder. The operator should keep the arc traveling forward just fast enough to keep it at the forward edge of the crater. This is the greatest speed of travel possible with the combination of reverse polarity, electrode diameter and current used. Advancing the arc less rapidly will result in a bead somewhat higher and wider to suit thickness for over $^3/_{16}$ inch. The weld must be thoroughly brushed with a steel brush in order to remove all oxide which forms on the weld.

The technique is the same as any arc welding with the exception that the welding current is in reverse polarity, as a bare rod is used for this work. Welding procedure to follow: The welder must weld crosswise on rim, from left to right and right to left, proceeding by weaving from side to side. This patch must extend over the edges of the rim in order to have squared up edges when the wheel is machined.

We use $^5/_{16}$- and $^3/_8$-inch diameter welding rods for this work. This rod is drawn from store in 20-foot lengths, and is cut up into 14-inch lengths and there is no waste or stub ends as the welder sticks the new piece onto the stub in this class of work.

Very little training is necessary before a welder can turn out consistently reliable results with this method on building up wheel centers.

The welding of cracked wheel centers has increased considerably due to the improved method of welding. Cracks that extend from journal fit through hub are cut out with a cutting torch, chipped and placed in a round furnace about 12 inches high, and covered with scrap car roofing. They are preheated with charcoal and a natural gas torch until hub is a medium red, then covered with asbestos, as welder must work over same. This work is done with the oxyacetylene process, and a good grade of $3^1/_2\%$ nickel welding rod is used. Charcoal is added to keep wheel at an even temperature. Two welders are used on this job, as it is rather difficult for one welder to work more than 25 minutes over the hot wheel. After welding, furnace is filled with charcoal and wheel is allowed to cool slowly—about 72 hours. This annealing process makes a better wheel as it machines very good and all road strains and stresses are removed.

Broken rim and spokes are welded with the electric arc method using heavy coated welding rod. Expansion is taken for broken spokes by heating adjacent spokes with an acetylene torch, small jack and wedge is used to take expansion for rim fractures. These welds are made with a double vee.

Tire retaining clips are welded to wheel center after tire has been applied. They extend over edges of tires $^5/_8$ inch. These are small forgings which keep tire from coming off in case it should become loose in service. Nine are applied to each wheel center. This is a safety feature, and has proved its worth on numerous occasions.

Boiler Check Valves

I have here a reversible boiler check valve and a boiler check elbow or seat. The maintenance cost of this type of brass valve and seat is very high, due to the continual opening and closing of the injector, which causes a heavy pound on this valve and seat. The result of this is the boiler check leaking, and in nearly all cases boiler checks had to be ground in after every trip.

After a careful study of this condition, we brazed a monel metal ring to valve seat, as monel combines high strength, toughness and resistance to corrosion. Brazed joint was tested to destruction in shop before test was made on engine. You can readily see the braze at the line of fusion is unharmed.

The first one was applied to switch engine 1279 that had to have boiler check ground in every day. The results obtained were better than expected, as valve and seat were only examined at time of monthly inspection. This is now our standard practice on all engines, as it has resulted in considerable savings.

Spring Rigging Work

The attention given to the equal distribution of weight and keeping of spring rigging to standard dimensions at all times has almost entirely eliminated hot journal boxes on our locomotives, and has cut down flange wear.

The importance of this is the centralization of all spring rigging work in shop at one point, where spring rigging is annealed, whitewashed and examined for cracks.

Main equalizer saddle, driving box cellar spacer, lateral triggers, saddles, strap hangers, stirrups, equalizers and grooves in band of springs are built up by electric welding and machined to standard dimensions. Plates are welded on driving box bearings of saddles and driving box equalizers, which are built up and machined as tires are worn down.

Foundation brake gear levers, brake beams, hangers, brake shoe heads and loose binder fits are welded and machined.

Engine truck rockers, equalizers, swing links and center castings are built up and machined to standard dimensions. Half round hardened bushings for rocker seats are welded in.

Worn sides of frames at shoe and wedge fits are built up with electric welding and are ground to standard dimensions with a special built grinder for this one job. This eliminates the breaking off of shoe and wedge flanges in service.

Driving Box Cellars

Recently occasion arose that on our long run 832 mile passenger engines, driving boxes, cellar boxes and binders had to be redesigned to hold 3 inch instead of $1^{7}/_{8}$ inch cake of grease in cellar. This was accomplished by extending lugs of driving box $^{3}/_{4}$ inch and plugging cellar bolt holes with electric welding. Three-fourth-inch piece brass was electric welded to top of cellar box radius and end plate to fit journal.

Full length plate $^{3}/_{4}$ inch thick was welded to bottom of binders, after which they were machined out $^{3}/_{4}$ inch on the inside to conform with cellar clearance.

Electric Welding with Bronze

One of the most remarkable developments is the electric welding with bronze. We are furnished with a very good grade of bronze that is cast in the Sacramento General Shops, and when applied to any wearing surface against steel last much longer than steel to steel. Several important jobs have become our standard practice.

Both wearing surfaces of radial buffer adjustable chaffing plates on our Mountain type passenger engines have this bronze applied. It is also applied to wearing surfaces of trailer and truck boxes and eccentric crank arm liners.

Bronze crosshead gibs that were formerly scrapped, now have their oversize bolt holes reduced and lateral maintained by building up. We apply a layer of bronze $^{1}/_{4}$ inch high and $^{1}/_{2}$ inch wide, crosswise on the extreme outer ends and center of gibs. These strips eliminate the breaking and sliding out of the babbit.

Bronze screen is electric welded to driving and truck boxes for securing babbit.

We have tried a good grade of phosphor bronze type "D" for the welding of worn journal crown brasses in box. Results from this were not satisfactory, as in the welding process the heat loosened the brass in the box. Results were not satisfactory welding brass out of box. However, we have not given up hope as I believe a way will be worked out that this work can be done without loosening brass in box.

Superheater Unit Work

On our type "E" superheater units we have experienced quite a bit of trouble due to units scaling up, burning and bursting at the ends nearest the fire. Different kinds of compounds and mixtures of acids were tried to remove scale, without results. This problem was temporarily solved by cutting the units off 24 inches from ends nearest fire and rewelding, after reaming tubes out with an 8-foot reamer. This did not do a clean job, as it left a thin layer of scale on walls and was not an ideal condition; for after a few months' service, scale was easily formed again, causing engines to be tied up for leaky units.

Sand blasting was then tried out with good results. A 20-foot $^{3}/_{8}$-inch pipe was inserted in tube and a thorough job of cleaning was accomplished.

The time and cost to cut these units was rather high, as this was all done with a hand hack-saw. Later, this time and cost was cut down less than one-half by acetylene cutter burning two holes in ends of units, and reaming large enough to insert pipe for sand-blasting, and holes welded after sand-blasting.

Hard-Surfacing Process

The process of hard-surfacing may be defined as the application of a thin coating of hard, wear-resisting alloy to the wearing surfaces of any type of metal parts. This means that a protecting layer of wear-resistant alloy covers the surface that is normally worn away rapidly and protects it from wear. This process is applied equally well to new parts before their first use, or to old worn parts. The use of hard-facing has resulted in an important savings in the maintenance of our stationary radial buffer castings between engine and tender. This is the casting that is bolted and welded to the engine. Before hard-facing was adopted in February 1930, the severe condition of abrasion and impacts wore these so badly after 12 to 18 months' service that they had to be built up to standard radii. We then started to build them up with a mild steel rod, machined them to standard radii, then applied a thin coating of hard facing material.

We have applied hard-facing material with oxy-acetylene, metallic arc and carbon arc methods, with and without coating on rod. We found that a greater saving can be effected by applying a thinner coating in the least possible time with the carbon arc method with a bare rod. The carbon is gripped as close to the arc as practical, for if a long length of carbon is exposed, the heating causes the carbon to vaporize and causes the carbon to burn away very rapidly, giving excessive wastage.

The dimension of surface we have to hard-face on a radial buffer casting is 11 inches x 16 inches or 176 square inches, which we do with $1^{3}/_{4}$ pounds of hard-facing material. This is done in one hour's time. In the 5 years we have applied hard-facing material to these

radial buffer castings, none have had to be renewed on account of wear.

Hard-facing is also applied to multiple throttle cam shafts, valves and ditcher bucket teeth.

Metal Spraying Process

One of the newest processes used in the railroad shop is the method of applying metals to surfaces with the metal spray gun. We have done some testing of metal spraying equipment, and find that we can reclaim our scrap monel pump rods and sleeves from feed water heaters by spraying with monel metal.

High carbon steel was sprayed to wearing surfaces of bronze link blocks and the life of these blocks was extended 3 to 5 times. This highly resistant wearing surface prevents galling of the link in the link block.

This method of applying metal has possibilities in the railroad field such as spraying surfaces to prevent corrosion.

Use of Welding for Shop Machinery

The use of welding in the repair and general maintenance of shop machinery is of foremost value. Repairs are made to machinery, castings and parts that could not be accomplished by other methods, thereby putting disabled equipment back into service in quick time and at a fraction of the cost of new parts, and avoiding delay especially to important shop operations.

The process has also made possible the construction and fabrication of many facilities that otherwise would not be provided.

Special tools and jigs are easily constructed with welding which is highly valuable toward efficient and economical shop operations.

We have had some interesting and unusual experiences in our shop, such as: Our large electric air compressor in power house that supplies the shop with air was disabled by an accident.

A large hole was knocked through wall into water space by valve dropping through worn valve seat. On first examination hole appeared to be about 8 inches x 10 inches but on taking this large cast-iron cylinder to the shop and after removing head, we found cracks extending under cylinder head.

All loose and cracked material was removed. To have ordered a piece of cast iron from foundry would have required two days. The coefficient of cubic expansion is about the same for steel so we rolled and fitted a piece of steel $1^1/_4$ inches x 14 inches x 18 inches. Before plate was fitted in we applied a $^1/_4$-inch layer of bronze on this steel plate so cast-iron piston head would not ride on steel.

Furance was built around this casting same night and welding job was completed next day. Casting was allowed to cool, and same was bored out and new seats applied. Air compressor was put in service again in the least possible time.

At another time, one of our traveling cranes was disabled by the collapse of a cast-iron motor rotor spider. We fabricated one out of steel plates and machined to size. This was balanced by drilling holes in end plates. As the crane was put up 31 years ago, it would have been impossible to replace rotor spider in a limited time. Crane was back in service in six days.

In store department, an elevator drum worm gear had all teeth broken. Outside companies were called in to bid on getting elevator back in service. The lowest bid was $500 and seven days to do the work. We did the job for $97 and elevator was back in service in two and one-half days. This was accomplished by machining all teeth off $^1/_2$ inch below root line and building up with bronze, and milling new teeth on worm gear.

Welding of Locomotive and Tender Parts

When engines come in shop that have met with accidents, such as pilot beams, tender frame castings and broken tender end sills, broken parts are fabricated of boiler plate and welded together.

Several months ago, we repaired the most completely wrecked tender frame I have ever seen. The rear end of tender frame was completely broken and crushed in. This tender frame was cast steel, and approximate cost of new section was about $2500.00, and it would have taken considerable time to cast same and ship to us from the east, which would have held this tender out of service 90 or more days.

The back tank head was removed, straightened and defective portion renewed. Rear end was completely fabricated from boiler plate, and two forgings we had made in our blacksmith shop. This was done at a fraction of the cost of new parts and avoided the long delay in getting tender back in service. Approximate cost was $362 for labor and $82 for material, total $444, for repairs to the whole tank as reflected by Shop Order.

Welding on Freight Cars

During the past year we have done more welding on freight car equipment, such as welding bottom rod supports, brake beam support angles, door tracks, side braces, corner gussets and threshold plates, as it is found that welding such parts is cheaper than riveting.

Scrapping of Vacated Equipment

The scrapping of locomotives and cars are operations of importance to our railroad. Undoubtedly the oxy-acetylene cutting torch is the major and most important tool employed for this work. Without it, the operations could not be carried out on the present profitable basis, as the cost of scrapping by entirely mechanical methods would in most cases be prohibitive. During the year 1935, 841 cars, 22 locomotives and 14 tenders were cut up at our scrap dock in Los Angeles.

As we progress, we must enter new fields—fields not yet fully explored. But in entering such fields, we must do so with caution, good judgment and discretion. Otherwise, we may tear down that which has been built up. Let us profit as we go through life by the experiences of others. Let your experiences and mine be given so that others may profit.

1935 BOUND VOLUME

Bound Volumes of the JOURNAL of the Society for the year 1935 are now available with imitation black leather covers. Contains a wealth of information on the latest developments in welding. Also contains Subject and Authors' Index. Price, $5.00 plus postage to members; $6.50 to non-members.

Physical-Chemical Phenomena of the Transfer of Metal during Welding

By G. M. TICHODEEV†

1. Introduction

FROM the metallurgical point of view, the process of arc welding may be divided into three stages. During the first stage fusion of a small part of adding metal takes place on the end of the electrode. The necessary heat is supplied (1) by the ions of the space of the cathode fall in the arc that give their kinetic energy to the fluid drop at the small area occupied by the cathode spot; (2) by the heat conduction and heat convection of gases heated to a very high temperature in the arc space; (3) by exothermic reactions taking place in the fluid drop.

During the second stage the metal passes from the end of the electrode into the liquid bath formed in the base material. At this moment the arc extinguishes and the temperature of the gases that surround the liquid metal decreases.

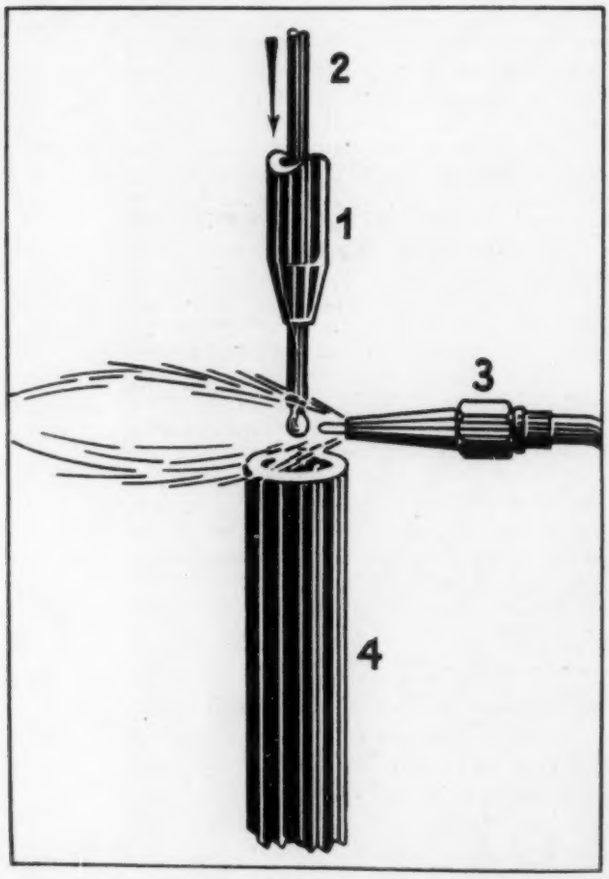


Fig. 1

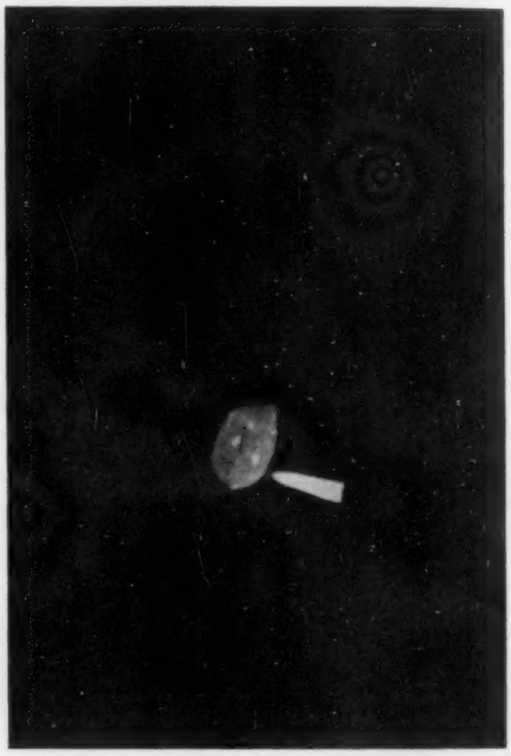


Fig. 2—Melting in Oxyacetylene Flame

During the third stage, the adding metal cools and crystallizes on the base material.

There is a very near analogy between the described processes and the well-known metallurgical processes, such as the melting of steel in the furnace and pouring into molds. Here, however, we meet specific peculiarities and owing to this fact we have to assume that the physical-chemical phenomena that take place in all the three stages are of nearly the same importance. Further, here we meet also electro-physical phenomena.

The purpose of our experiments was to find out: (1) what changes take place in the chemical composition of the drop of molten metal when it is being formed at the end of the wire; (2) what laws govern the falling of the fluid drop of metal from the end of the electrode when there are no factors of electrical nature (e.g., the pinch-effect) and it takes place only under the influence of its own weight.

2. Experimental Part

We have chosen for our investigations wire of carbon steel divided into three groups. In the first group the content of carbon varied from 0.07 to 0.48 per cent while the contents of manganese and silicon were constant, the

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first being about 0.42–0.51 per cent and the second 0.21–0.24 per cent. In the second group the content of manganese varied from 0.36 to 1.03 per cent and the contents of C and Si were constant, the first being about 0.07–0.15 per cent and the second 0.20–0.24 per cent. In the third group the content of silicon varied from 0.20 to 0.54 per cent and the contents of C and Mn were constant, the first being about 0.07–0.12 per cent and the second 0.42–0.48 per cent. The full chemical analysis of the wire is given in Table 1.

Table 1—Chemical Composition of the Wire

Wire No.	C, Per Cent	Si, Per Cent	Mn, Per cent	S, Per Cent	P, Per Cent
1	0.07	0.22	0.42	0.014	0.016
2	0.13	0.24	0.45	0.010	0.017
3	0.18	0.22	0.46	0.010	0.017
4	0.25	0.21	0.46	0.014	0.015
5	0.37	0.21	0.46	0.016	0.016
6	0.41	0.22	0.46	0.012	0.012
7	0.48	0.21	0.51	0.012	0.014
8	0.11	0.20	0.36	0.014	0.014
9	0.07	0.24	0.66	0.008	0.016
10	0.15	0.23	0.86	0.006	0.015
11	0.12	0.20	1.03	0.008	0.018
12	0.12	0.28	0.46	0.012	0.012
13	0.09	0.34	0.48	0.008	0.012
14	0.10	0.54	0.48	0.006	0.010

The wire was made of steel melted of very pure raw material in a small high-frequency furnace in an acid crucible. Deoxidation was done with silicon. Ingots have been obtained weighing 25 kg. After cutting off the head, the ingots were forged into billets 45 x 45 mm.^{2} in section, that were then rolled into rods, 8 mm. in diameter. Wire 4 mm. in diameter was drawn from these rods.

The following experiments have been carried out. The wire was slowly fed at a constant rate in the vertical position by means of a mechanism into the zone of the welding flame in such a way that the end of the wire was being melted and drops of fluid metal were repeatedly falling down. In Fig. 1 is shown a nipple (1) along which the wire (2) was fed; the end of the wire was all the time in the zone of welding flame of the gas torch (3) or of the electric arc. The drops of fluid metal were falling into a cylinderical narrow vessel containing water (4), where they cooled and solidified. The distance of the level of water in the vessel from the end of the electrode was equal to about 3 cm.

In order to examine the influence of the nature of gaseous medium, the fusion was carried out under different conditions, namely: (1) in oxyacetylene neutral flame, (2) in oxyacetylene oxidizing flame, (3) in the flame of the tungsten arc in hydrogen atmosphere, (4) in the flame of carbon arc in air.

When the wire was being fused in oxyacetylene neutral flame, the pressure of oxygen was equal to 2 atm., that of acetylene to 1 atm.; a torch was used having a tip No. 4. The distance between the end of the nucleus of the flame and the surface of the drop of metal was about 2–3 mm. When the wire was being fused in the atomic-hydrogen flame, the hydrogen pressure was equal to 0.3 atm.; the diameter of the tungsten electrodes was 3 mm. and the arc current was equal to 40 A. The part of the wire that was being fused was in the flame of the arc at the distance of 15 mm. from the ends of the electrodes. When melting in carbon arc, the same electrode-holder as in the preceding experiments was used and instead of tungsten electrodes, carbon electrodes 7 mm. in diameter were gripped. The current of the arc was equal to 55 A. The arc had the form of a stretched tongue 25–30 mm.

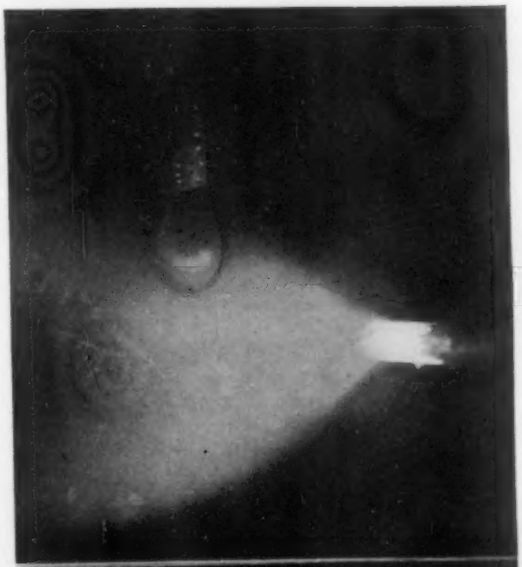

Fig. 3a—Atomic Hydrogen Flame

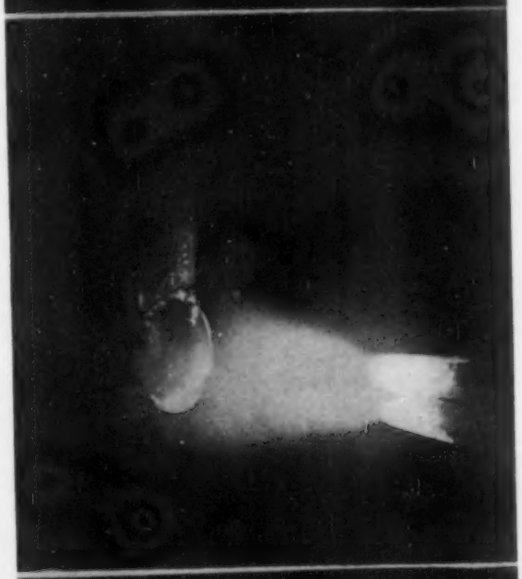

Fig. 3b—At the Moment of Tearing Away

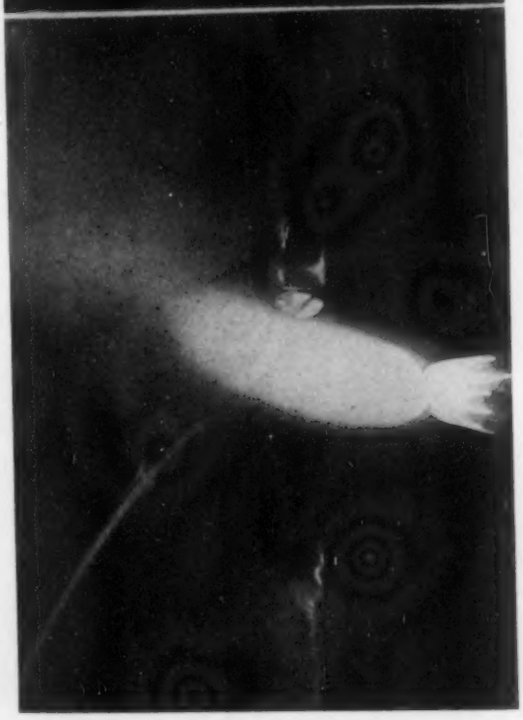

Fig. 3c—Formation of New Drop

long. The distance between the end of the wire and the ends of the electrodes was 15 mm.

Before every experiment of fusion, the gas torch or holder was fastened in a massive support and the same distance between the axis of the rod and the end of the torch was carefully maintained. The flame of the gas torch and of the electric arc was also carefully regulated. The velocity of movement of the wire was regulated in connection with the velocity of fusion, and the fluid drop was all the time while it was being formed in the same gaseous medium.

In Fig. 2 is shown a photograph when the wire is being fused in oxyacetylene flame. On the surface of the fluid drop four light spots may be seen. The spot nearest to the nucleus of the flame is a reflex; the other three spots and one of them in the lowest point of the drop are small heaps of liquid slag and they float easily on the surface.

In Fig 3 the moment of the drop formation and falling is shown when the wire is being fused in the atomic hydrogen flame. Owing to the lower pressure of the gas jet, no deviation of the drop happens (Fig. 3*a*).

The moment of the tearing away of the fluid drop is shown in Fig. 3*b*. This photograph shows the form of the drop at the place where it was torn away. At the lower part of the drop a small accumulation of slag in the form of a thin film is seen.

In Fig. 3*c* is shown the moment of the falling of the drop and the formation of a new one. After the drop has been torn away, it quickly acquires a spherical shape 7–8 mm. in diameter. The light winding line stretching along the traces of the drop is the accumulation of slag.

Each separate experiment of fusion lasted as much time as was necessary to obtain 18–25 drops. When melting in oxyacetylene flame, the frequency of the falling of the drops was equal to approximately 10–12 drops per minute, in atomic hydrogen flame 12–15 drops per minute and in the carbon arc 20–25 drops per minute. The solidified drops had a round irregular form, hollow inside.

The drops collected from every experiment were being dried and then weighed together within ±1 mg. By dividing the total weight of drops by their number, the average weight of one drop was determined. The results of weighing separate drops have shown that in most cases their weights are very near to the average value, the maximum deviation being about 5–10 per cent. In separate cases the deviations amounted to 50 per cent; this could be observed in such cases when the fusion of the rod proceeded wildly and was accompanied by the spattering of small drops. There is reason to assume that in the last case the reaction of the combustion of carbon into carbon monoxide contributes to the tearing away of the drops.

In Figs. 4–6 the results of the experiments are shown. The chemical analysis of the drops is given in Tables 2 and 3.

3. Discussion of Results

The data of chemical analysis will be considered first. On the basis of these data one general conclusion may be drawn, namely, that gaseous mixtures of any welding flame possess in a more or less degree oxidizing properties. In the rising order of oxidizing properties the media investigated are as follows:

(1) Oxyacetylene neutral flame,
(2) Atomic hydrogen flame,
(3) Oxyactylene oxidizing flame,
(4) The flame of the carbon arc in air.

In all the experiments of fusion, the burning of silicon is very high. When the initial amount of silicon in the rod is 0.20–0.22 per cent, there remain after fusion in the oxyacetylene and atomic hydrogen flame 0.05–0.10 per cent of Si and after fusion in carbon arc less than 0.05 per cent. The burning of manganese amounts to less than 50 per cent of its initial content when fusion is carried out in the neutral oxyacetylene flame but to an amount a little more than 50 per cent in the oxidizing flame and to more than 75 per cent when fusion is carried out in the carbon arc.

As regards carbon, maximum burning—approximately one-half of its initial content—takes place when fusion of wire containing 0.25–0.48 per cent C is carried out

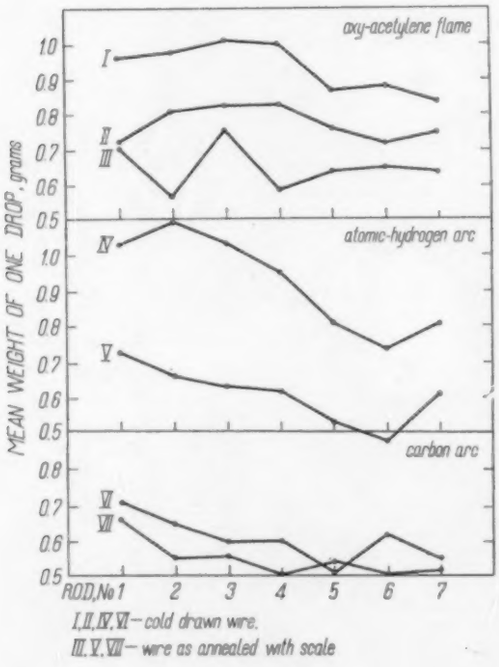
oxy-acetylene flame
atomic-hydrogen arc
carbon arc
MEAN WEIGHT OF ONE DROP, grams
ROD, No 1 2 3 4 5 6 7
I, II, IV, VI – cold drawn wire.
III, V, VII – wire as annealed with scale

Fig. 4

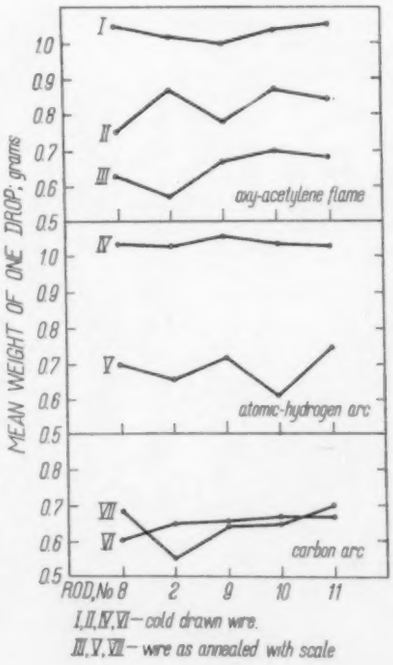
oxy-acetylene flame
atomic-hydrogen arc
carbon arc
MEAN WEIGHT OF ONE DROP, grams
ROD, No 8 2 9 10 11
I, II, IV, VI – cold drawn wire.
III, V, VII – wire as annealed with scale

Fig. 5

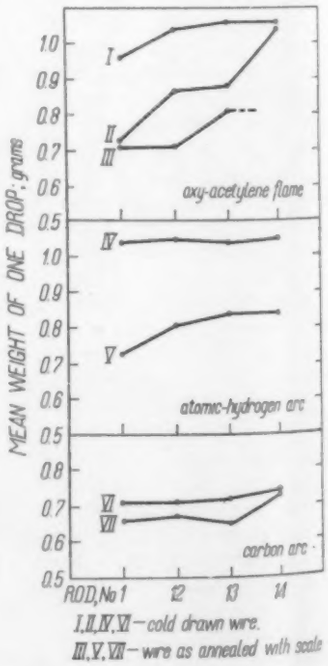
oxy-acetylene flame
atomic-hydrogen arc
carbon arc
MEAN WEIGHT OF ONE DROP, grams
ROD, No 1 12 13 14
I, II, IV, VI – cold drawn wire.
III, V, VII – wire as annealed with scale

Fig. 6

Table 2—The Chemical Composition of Drops Obtained during Fusion in Oxyacetylene Flame

The Conditions of Experiments	Wire No.	C Content Per Cent In the Wire	C Content Per Cent In the Drops	Si Content Per Cent In the Wire	Si Content Per Cent In the Drops	Mn Content Per Cent In the Wire	Mn Content Per Cent In the Drops
Fusion in oxyacetylene neutral flame	1	0.07	0.14	0.22	0.07	0.42	0.23
	4	0.25	0.23	0.21	0.10	0.46	0.24
	7	0.48	0.42	0.21	0.08	0.51	0.29
	11	0.12	0.14	0.20	0.06	1.03	0.65
	14	0.10	0.16	0.54	0.47	0.48	0.42
Fusion in oxyacetylene oxidizing flame	1	0.07	0.11	0.22	0.05	0.42	0.16
	4	0.25	0.24	0.21	0.05	0.46	0.18
	7	0.48	..	0.21	..	0.51	..
	11	0.12	0.13	0.20	0.03	1.03	0.49
	14	0.10	0.11	0.54	0.16	0.48	0.12

Table 3—The Chemical Composition of Drops, Obtained during Fusion in the Tungsten Arc in the Atmosphere of Hydrogen and in the Carbon Arc in Air

The Conditions of Fusion	Wire No.	C Content Per Cent In the Wire	C Content Per Cent In the Drops	Si Content Per Cent In the Wire	Si Content Per Cent In the Drops	Mn Content Per Cent In the Wire	Mn Content Per Cent In the Drops
Fusion in the tungsten arc in the atmosphere of hydrogen	1	0.07	0.06	0.22	0.07	0.42	0.22
	4	0.25	0.20	0.21	0.06	0.46	0.20
	7	0.48	0.32	0.21	0.06	0.51	0.24
	11	0.12	0.09	0.20	0.05	1.03	0.60
	14	0.11	0.09	0.54	0.38	0.48	0.37
Fusion in the carbon arc in air	1	0.07	0.08	0.22	0.03	0.42	0.09
	4	0.25	0.12	0.21	Traces	0.46	0.10
	7	0.48	0.29	0.21	0.04	0.51	0.12
	11	0.12	0.09	0.20	Traces	1.03	0.23
	14	0.10	0.10	0.54	0.11	0.48	0.16

in carbon arc. The burning of carbon in wire containing 0.07–0.12 per cent C is insignificant. The burning of carbon is also insignificant during fusion in atomic hydrogen flame and in oxyacetylene neutral flame; even slight decarburization may take place.

From the numerical values the following conclusion may be drawn. Silicon burns with maximum rate; manganese stands in the second place. Both elements are oxidized not by direct combination with O_2 from the surrounding gases but chiefly by means of the reducing reaction with FeO dissolved in the fluid drop. Now, since the reaction of ferrous oxide reduction with silicon is accompanied by evolution of heat, its burning will take place from the very beginning of the fluid drop formation while the temperature of the latter is comparatively low, namely, near its melting temperature. The same holds true for the oxidation of manganese. After the concentrations of Si and Mn decrease and the temperature of the drop rises, carbon begins to react with ferrous oxide and this is accompanied by heat absorption. Spark formation that had taken place just before the tearing away of the drop pointed out acceleration of the reaction of carbon burning just at the end of the drop formation. The temperature of the drop is probably at this moment about 1600–1650° C.

We may assume that changes in the chemical composition of the adding metal during arc welding that take place in the fluid drop at the end of the bare electrode differ only slightly from those in our experiments of wire fusion in the carbon arc. Let us therefore compare them with the data of chemical analysis of small deposits obtained by means of arc welding with bare electrodes (Table 4).

When the initial content of carbon in the rod is 0.07–0.012 per cent, the burning of this element at the end of the electrode amounts approximately to one

Table 4—The Burning of Elements during Arc Welding

	Wire Nos. 1	4	7	11	14
Carbon					
1. The content of C in the wire, per cent	0.07	0.25	0.48	0.12	0.10
2. The content of C in the deposit, per cent	0.04	0.10	0.19	0.05	0.04
3. The content of C in the drop at the end of the electrode, per cent	0.08	0.12	0.30	0.09	0.10
4. The burning of C at the end of the electrode, in per cent of the initial content	0	52	38	25	0
5. Total burning of C after welding, in per cent of the initial content	43	60	60	58	60
Silicon					
1. The content of Si in the wire, per cent	0.22	0.21	0.21	0.20	0.54
2. The content of Si in the deposit, per cent	Traces				
3. The content of Si in the drop at the end of the electrode, per cent	0.03	0.01	0.04	Traces	0.12
4. The burning of Si at the end of the electrode, in per cent of the initial content	86	95	81	100	78
5. Total burning of Si after welding, in per cent of the initial content	100	100	100	100	100
Manganese					
1. The content of Mn in the wire, per cent	0.42	0.46	0.51	1.03	0.48
2. The content of Mn in the deposit, per cent	0.08	0.14	0.24	0.25	0.08
3. The content of Mn in the drop at the end of the electrode, per cent	0.09	0.10	0.12	0.22	0.16
4. The burning of Mn at the end of the electrode, in per cent of the initial content	79	78	78	79	66
5. Total burning of Mn after welding, in per cent of the initial content	81	70	53	75	84

quarter of the initial content, and when the initial content is 0.25–0.48 per cent the burning amounts to about one half of this initial content. The total burning of carbon in the process of welding amounts to 50–60 per cent of its initial amount in the rod.

As regards silicon, it burns out in a large degree—about 80–90 per cent—at the end of the electrode at any content of silicon within 0.20–0.54 per cent.

No relationships could be found as regards the burning out of manganese, probably due to the fact that the loss of Mn takes place not only as the result of oxidation but also because of evaporation. The conditions of the fusion of wires in the carbon arc and during arc welding are not identical and it is possible that in the first case the evaporation of Mn is higher than in the second one.

It became of interest to find whether any absorption of nitrogen from the surrounding atmosphere took place during the process of fusion. These determinations were carried out on a small scale considering the difficulty of the exact determination of nitrogen in steel. The analysis was carried out by the method of dissolution in hydrochloric acid and distillation. The data given in Table 5 are mean values of two determinations.

The increase of the nitrogen absorption during fusion in atomic hydrogen flame and in the carbon arc does not contradict our ideas of nitrogen activity under the conditions of the electric arc.

Before we go over to the discussion of the weights of the drops shown on the curves of Figs. 4–6, the phenome-

Table 5—Nitrogen Content in Drops

The Conditions of Experiments	Wire No. 8	Wire No. 12
N_2 content of the wire, per cent	0.0033	0.0035
N_2 content after fusion in oxyacetylene neutral flame	0.0071	0.0070
N_2 content after fusion in oxyacetylene oxidizing flame	0.0158	0.0061
N_2 content after fusion in atomic hydrogen flame	0.0264	0.0143
N_2 content after fusion in carbon arc	0.0457	0.0253

non of surface tension which is the cause of the drop formation should be discussed.

On the basis of the science of molecular forces it is considered that liquid is enveloped in an elastic film consisting of its surface molecules. The modern physics begins to recognize the existence of a quasi-hard layer on the surface of liquid. On this basis we may picture to ourselves the formation of drops when flowing out of the end of a narrow tube or during fusion of a metallic rod as gradual accumulation of liquid in an elastic bubble fixed at the end of the tube, the walls of which (of the bubble) expand due to the weight of the liquid. The size of the drop increases until the walls of the bubble are torn. The force of the tearing away per unit length of the line of rupture is taken as the measure of surface tension. The line of rupture is the line of circumference of the neck of the drop, where it tears away from the rest of the liquid. The surface tension is calculated by the formula $x = mg/2\pi r$, where m is the mass of the drop, g the acceleration of gravity, r the radius of circumference at the neck.

Thus, the results of our experiments may be interpreted from the point of view of the manifestation of forces of surface tension.

The value of the surface tension for iron in air was determined by Quincke in 1869. By using the method of measuring the height of the drops, he obtained numerical values of the coefficient of surface tension at the melting temperature within 950–970 dyn/cm. Later, G. Draht and F. Sauerwald[1] determined the surface tension of cast iron in hydrogen atmosphere by the method of blowing gas through the liquid. By raising the temperature of the cast iron from 1267° to 1318° the surface tension changed from 936 to 914 dyn/cm.

In so far as for our purposes it was enough to determine the relationships as regards the comparative changes of the weight of the drops, we did not try to measure the absolute value of surface tension. This value may be found approximately from our experiments if we assume that the diameter of the neck of the drops when tearing away is a constant value equal to 0.8 of the wire diameter. When the diameter of the wire is 0.4 cm., the diameter of the neck is equal to 0.32 cm. and the circumference to 1 cm.

This agrees with the dimensions of the tearing away drop, shown in Fig. 3*b*. Thus the values (given on the curves) of the average weights of drops give also the approximate value of surface tension in g./cm. If we multiply this value by 981, we obtain surface tension in dyn/cm.

Considering the curves in Figs. 4–6, it should be noted that during fusion of low-carbon wire in neutral oxyacetylene flame and in atomic hydrogen flame, the average weight of the drop is equal to about 1 g. and is quite a constant value. The value of surface tension coefficient obtained from it is in near agreement with Quincke's data.

[1] *Z. für anorg. und. allgem. Chemie*, 1927, No. 4.

In three grades of wire Nos. 5, 6 and 7 containing from 0.37 to 0.48 per cent of carbon, the average weight of drops decreased to 0.86 g. during fusion in oxyacetylene flame and to 0.79 g. during fusion in atomic hydrogen flame. This may be accounted for by the fact that when there is a large content of carbon, a part of it forms carbon monoxide that expands and untimely tears away the drop being formed.

In the experiments of fusion in strongly oxidizing atmosphere, another factor beings to exert an influence on the decrease of the average weight of drops. This factor is the formation of a large quantity of slag consisting of oxides of iron and impurities on the surface of the drop. The average weight of the drop decreases also in such cases when the melting is being done in a neutral gaseous medium, but after annealing the rod is covered with a layer of scale. The effect of a large quantity of slag formed due to the melted scale tells also here. This slag accumulated chiefly above at the base of the drop and in case of fusion in the carbon arc it formed a kind of collar around the drop of metal. It may be seen from the curves that in the case of fusion in the carbon arc in a strongly oxidizing atmosphere or in the case of fusing the wire together with scale, the average weights of the drops decrease by 30–40 per cent.

This decrease of surface tension may be accounted for by two reasons. Firstly, during fusion in a strongly oxidizing atmosphere the formation of a large amount of slag takes place which forms at the surface of the drop a layer of a second liquid that does not intermix. Then the forces of attraction of the reverse sign of the molecules of the surface layer of fluid slag will affect the molecules of the surface layer of metal and thus the surface tension in the boundary layer will be decreased. Secondly, on the interface slag-metal in the adsorption layer of the metallic drop ferrous oxide is dissolved; the amount of the latter depends on the content of free ferrous oxide in slag. The surface tension depends in a very high degree on the properties of the adsorption layer, and in particular we may assume that ferrous oxide dissolved in a sufficient amount in this layer contributes to a considerable decrease of surface tension.

4. Summary

1. The aim of the fusion tests in different gaseous media was to investigate two problems:

(*a*) The changes in chemical composition of the molten metal that take place during the formation of the drop at the end of the electrode;

(*b*) The laws that govern the tearing away of the drops of fluid metal from the end of the electrode wire during arc welding if there were no factors of electrical origin.

2. Different gaseous media of the welding flame may be arranged in the following rising order as regards their oxidizing properties:

(*a*) Oxyacetylene neutral flame,
(*b*) Atomic hydrogen flame,
(*c*) Oxyacetylene oxidizing flame,
(*d*) The flame of the carbon arc in hydrogen atmosphere.

3. During fusion in the first two gaseous media, minimum burning of elements takes place, namely, the burning of carbon is insignificant; the burning of silicon amounts to 60–70 per cent and that of manganese to 50 per cent. Maximum burning takes place during fusion in the carbon arc, namely, the burning of carbon amounts to 25–50 per cent; that of silicon 80–90 per cent and that of manganese 80 per cent.

4. The conditions of fusion tests in the carbon arc allow to assume that the results of these tests as regards

the burning of elements apply also to arc welding with a bare metallic electrode. This is of a theoretical interest for the elucidation of the order of oxidation of elements present in the adding metal at the end of the electrode, and in the liquid bath on the base metal. The greater part of carbon is oxidized in the molten metal in the crater; almost the whole content of silicon is oxidized at the end of the electrode; more than half the content of manganese burns out at the end of the electrode.

5. Taking in view the above conclusion, we may infer that in order to obtain conditions of minimum oxygen absorption and minimum burning of elements in the case of arc welding with a metallic electrode, one should aim to full protection of the fluid metal at the end of the electrode against the effect of the surrounding air.

6. The average weight of drops tearing away due to their own gravity in the case of fusion of low-carbon wire 4 mm. in diameter in a neutral gaseous medium is equal to about 1 g. and does not vary perceptibly when the content of carbon varies from 0.07 to 0.25 per cent, that of silicon from 0.22 to 0.54 per cent and that of manganese from 0.36 to 1.03 per cent. When the content of carbon is more than 0.25 per cent, the average weight of the drop decreases due to its untimely tearing away as affected by the generated carbon monoxide. The average weight of the drops during fusion of the wire in a strongly oxidizing gaseous medium decreases by 30–40 per cent.

7. Considering the variations in the average weight of the drops from the standpoint of the change of surface tension, we have to conclude that during fusion in an oxidizing medium the surface tension decreases considerably. This decrease of the surface tension is due to the influence of a layer of fluid slag covering the drop. The influence of slag may be accounted for in two ways: (*a*) the surface tension in the boundary layer between two liquid phases slag-metal decreases due to the interaction of the molecules of these two phases; (*b*) the adsorption layer of the fluid drop is saturated with ferrous oxide that decreases the surface tension of metal.

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WELDING SOCIETY ACTIVITIES AND RELATED EVENTS

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One of the tasks of your Meetings and Papers Committee is to anticipate the needs and wishes of the membership at large in planning programs for national meetings and the contents of the Journal. Suggestions have been frequently received from members who desire particular types of paper included in the Journal, and the Committee has always welcomed such requests.

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* * *

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An Introduction To Physical Metallurgy

This book published by McGraw-Hill Book Company, New York City, was prepared by Leland Russell Van Wert, Lecturer on Metallurgy, Graduate School of Engineering, Harvard University. The book is a brief exposition of fundamental physical metallurgical principles and is an outgrowth of the course of lectures given at Harvard University. The book includes the following chapters: What Is a Metal? The Metals and Their Properties. The Equilibrium Diagram: The Liquid–Solid Change. The Microconstituents of Alloys. The Properties of

Alloys. The Mechanical and Thermal Treatment of Metals and Alloys. Price $3.00.

Nomination Ballot

On the 1936 Nomination Ballot the name of F. M. Farmer, a member of the Nominating Committee, was inadvertently omitted.

Mr. Farmer attended and participated in the selection of nominees for elective offices to be filled at the Annual Meeting in 1936.

Translations

Through the courtesy of one of the cooperating companies the Society has available two copies of a translation entitled "Stresses in Welding," by Dipl. Ing. E. Helfrich, Halle a. d. Saale, translated from *Die Wärme*, Vol. 55, No. 39, Sept. 24, 1932. This is in connection with a program of mutual cooperation in such matters established by the Fundamental Research Committee. The Society is glad to loan these copies upon request.

Welding Engineer

The AMERICAN WELDING SOCIETY acknowledges with grateful appreciation a donation of Volumes 1 to 4 of the *Welding Engineer* made by Mr. W. B. Lasher, Jr., Director of Research of the American Chain Company, Inc. These additions to the library of the Society complete the file of the *Welding Engineer*.

This generosity is particularly appreciated by those who wish to occasionally refer to some early development in welding.

Welding Technology and Design

A book on the above subject published by J. B. Lippincott Company, Philadelphia, has been prepared by Messrs. G. F. P. Fox and F. Bloor. This book is 90 pages and contains information and data design for filling a long-felt need among draftsmen and technicians. The book sells for $1.50.

Airco Electric Catalog

Electric welding products—electrodes, arc welding machines and miscellaneous apparatus—are well described and illustrated in a thirty-two page book recently issued by the Air Reduction Sales Co., 60 East 42nd Street, New York City.

The first section of the book is devoted to electrodes, of which there are some thirty-nine—bare, coated, cast iron and bronze, and Stoody rods for hard-facing, etc.—and for each is a paragraph stating recommended uses, physical properties, welding procedure and a general description of flowing qualities, penetration, etc.

Miscellaneous apparatus comes next—helmets, face shields, cables, lungs, plates, gloves, brushes and electrode holders—all illustrated and well described.

The third part takes up the subject of Wilson arc welding machines (distributed nationally by Air Reduction) and is introduced by an interesting article showing the durability of these machines in action. A complete description of the make-up of the machines and their various advantages is followed with illustrations of the different types—the Wilson A.C. Transformer Type being singled out for special attention.

The last section consists of a group of tables especially useful to the welder, such as an arc welding table, a chart of recommended arc voltages, recommended amperages, approximate weights of Airco rods and an excellent summary of the causes of bad welds.

SECTION ACTIVITIES

BOSTON

Prof. A. V. deForest of the Massachusetts Institute of Technology will speak before the Boston Section at its meeting on March 20th. The meeting will be held in Room 5-330, M. I. T., at 7:30 P.M.

CHICAGO

The February meeting of the Chicago Section was held on the 28th, at the Mission Hall, Armour Institute of Technology. "Welding and Cutting on Railroads" was the subject of the meeting. A lecture course on "Metallurgy as Applied to Welding," by Jules Muller of the Chicago Steel and Wire Company was first on the program. Mr. Otto Gier, Superintendent of Welding, Grand Trunk Western R. R., described welding operations as performed in railroad shops. Mr. Charles M. Lammers, Supervisor of Welding and Metallurgical Chemist, Chicago & Eastern Illinois Railway, spoke on "Reclamation Welding—Its Field, Its Faults." Motion pictures showing welding and cutting operations in some of the large railroad shops were shown through the courtesy of the Oxweld R. R. Service Company.

CLEVELAND

The Cleveland Section held their fourth regular meeting of the season Wednesday evening, February 12th, at the Cleveland Engineering Society. There were about sixty-five present. Mr. Louis J. Larson, Director of Welding Research of the A. O. Smith Corporation of Milwaukee, spoke on "An Exploration of the Modern Metallic Arc." The talk was illustrated by slides. In addition to describing some experiments dealing with the behavior of the metallic arc, Mr. Larson discussed some of the results accomplished in the use of such an arc.

DETROIT

The monthly meeting of the Detroit Section was held on February 27th. "Short Timing Control in Resistance Welding"—a lecture fully illustrated with operating timers—was presented by Mr. J. W. Dawson, Control Engineer of the Westinghouse Electric & Manufacturing Company.

LOS ANGELES

The January 23rd meeting was held in the Chamber of Commerce Building with sixty-two present. Mr. Turner C. Smith gave a discussion on progress of "Structural Steel Welding Course." Mr. Frank Howard elaborated on Mr. Smith's talk.

The following officers and executive committee were elected:

Chairman—Jim Blake, Victor Welding & Equipment Co.
Vice-Chairman—Wayne Howard, General Petroleum Company.
Secy. & Treas.—Russell L. Graves, Union Oil Company.
Executive Committee:
Frank Howard, Smith-Emery Co.
R. W. Binder, McClintic-Marshall Co.
P. D. McElfish, Standard Oil Co.
G. L. Parsons, Lincoln Electric Co.
C. P. Sanders, Western Pipe & Steel Co.
Frank Emery, Air Reduction Sales Co.

Mr. P. G. Baker of Roscoe Moss Company gave an interesting talk on the new Atomic Hydrogen Welding Process and its application in the Roscoe Moss plant, of which Mr. Baker is Chief Engineer. His talk was very enlightening on the problem of welding hard steel.

Mr. Cipperly of General Electric followed this talk with a detailed description of the Atomic Hydrogen Flame and Apparatus that is used to apply it. Both talks were interesting and appreciated.

NEW YORK

The regular monthly meeting of the New York Section will be held on March 10th. Mr. A. B. Kinzel, Chief Metallurgist of the Union Carbide and Carbon Res. Labs., will speak on "Low Alloy, High Tensile Steels," and Mr. H. M. Priest, Engineer, Railroad Research Bureau, Subsidiary Mfg. Companies, U. S. Steel Corp., will present an address on "Applications of Low Alloy, High Tensile Steels." Lively and interesting discussion is expected.

The April meeting of the Section will be held on April 14th in Room 501, Engineering Societies Building, and the subject will be "Welding in Shipbuilding."

PITTSBURGH

Mr. E. W. Forker, Manager of the Process Equipment Division of the Blaw-Knox Company, spoke before a large attendance of the Pittsburgh Section members and guests, Wednesday, February 19th, at the Roosevelt Hotel.

The method of fabrication of the Everdur, stainless steels and alloys was thoroughly covered and with the use of slides and charts the subject was made exceptionally interesting to those present. Slides showing the large number of various pieces of equipment manufactured by the Blaw-Knox Company were shown and discussed by Mr. Forker.

Representatives from most of the industrial plants and companies manufacturing equipment for oil companies were present.

Following the talk the meeting was thrown open for general discussion and inspection of the many samples of welded metals on display.

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